European Commission

Research Programme of the Research Fund for Coal and Steel

Technical Group: TGC1

Project Title

Enhanced effectiveness and safety of rescuers involved in high risk activities by designing innovative rescue equipment systems

Acronym

INREQ

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Grant Agreement number

RFCR-CT-2012-00002

start date – end date of project

01.07.2012– 30.09.2015

Final Report

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1. FINAL SUMMARY

The most significant aspects on a task by task basis: project objectives, results obtained and their usefulness, conclusions and possible applications and patents.

1.1. WORKPACKAGE 1: DETERMINATION OF REQUIREMENTS AND SPECIFICATIONS OF NEW RESCUE EQUIPMENT

Work within WP1 was focused on determination of technical assumptions for all planned rescue devices, such as lightweight rescue conveyor, rescue support and air conditioner, as well as for MK3 m-Comm communication system and climate measuring device (CMD).

1.1.1. Results obtained of Task 1.1: Determination of assumptions for prototype and experimental rescue equipment (CSRG, AITEMIN, ICOP, KOMAG, Geocontrol)

Due to experience of CSRG in the field of mine rescue, it was possible to develop initial assumptions and guidelines for rescue equipment. CSRG in cooperation with KOMAG defined the parameters and requirements for the rescue conveyer, rescue support and air conditioner.

Conveyor with its shuttle platform, rescue tunnel support and air conditioner were initially modelled in 3D technology. Obtained 3D models were used for FEM and MBS verifying virtual calculations. FEM calculations enabled to indicate weak points in each design and to make corrections, in a result of what the final design versions of sub-systems of each device were obtained. Specialists from KOMAG developed special, effective technology for extension of the conveyor by 3 m i.e. by 3 troughs for every step of extension, during development of rescue tunnel with use of shuttle platform to transport indispensable equipment – support legs, canopies, troughs and chain.

Technology for mining the compact rocks through destroying the rock mass cohesion, used among others in development of rescue tunnels, was considered in task. The simple, effective technology for mining the rocks of uniaxial compression strength exceeding 100 MPa and of relatively low energy consumption, is the aim of suggested method.

It was agreed that the micro-tunnelling device should be made according to the displacement strategies used by traditional Tunnel Boring Machines (TBM), which advances by means of hydraulic jacks pushing against fixed elements (such as support frames) on the surface of the tunnel, driving the whole machine forward.

Conclusions: Technical assumptions for each device were developed, what is reflected in D1.1. Despite resignation of manufacture of hydro-cutting device within the project the assumptions for this device remain valid for the targeted device.

1.1.2. Results obtained of Task 1.2: Initial 3D modelling of equipment (KOMAG, Geocontrol)

According to the assumptions developed in T1.1, modelling the equipment in Inventor software programme was prepared. Virtual, versatile verification of the equipment design was the modelling objective. Models useful for development of technical documentations were the result of modelling. However, before it happens, responsible structural components and nodes were verified by the FEM method. Models of each conveyor subassembly enable carrying out FEM analyses, virtual assembly of conveyor components, simulation of shuttle platform travel and relative movement of the route components. Geocontrol made FEM analyses of the conveyor trough. The developed models were also used for creation of virtual simulations in close collaboration between Geocontrol and KOMAG. Created models of devices were delivered to GEOCONTROL and they verified these devices through virtual visualizations of rescue action.

Technical parameters of electric motor, compressor, heat exchangers, and expansion valves designed for air conditioner were determined.

Conclusions:

- The models were accepted by the specialists from CSRG.
- FEM analyses confirmed the correctness of models designs.
- The models were accepted for further work within WP 2.
- The model of shuttle platform requires emergency device, which would help to stop the platform by the travelling rescuer at any place on the track.
- Work was realized within WP 2 T2.1 "Design studies of equipment prototype".
- The models were useful for virtual simulation of rescue action.

The conclusions are completed within deliverable D1.2.

1.1.3. *Results obtained of Task 1.3: Specifications for data transfer system protocols and interfaces (GAUK, CSRG)*

CSRG determined the minimal requirements to be fulfilled by the system of rescue communication on the basis of requirements imposed by the relevant regulations. Task 1.3 enabled establishing the outline of a data protocol that would be capable of transmitting gathered information from external transponders and portable equipment/meters. The development and design parameters of the m-Comm data link depended on the selection and specification of suitable sensors and data from portable monitoring equipment.

GAUK specified the parameters and assumptions for the necessary modifications of the m-Comm system to enable data transfer whilst maintaining a high level of integrity for voice communication. This included determining the transmission rates and protocols for the wireless module, hub unit and base units interface circuits.

Conclusions:
The calculations and successful optimization of the data format and the data package size for silent transmission via the audio link were completed. Deliverable D1.4 relates to Task T1.3, specifications for data transfer system protocols and interfaces, and were completed.

1.1.4. *Results obtained of Task 1.4: Specification of measurements of biometric and mine atmosphere parameters (GAUK, DMT, CSRG, Geocontrol)*

The partners worked together to determine the candidate sensors for data monitoring relating to biometric monitoring and environmental monitoring. CSRG listed their requirements (and specification) for environmental gasses, temperature and humidity sensors, and included a specification for the rescue communications system. It was originally envisaged that the biometric monitoring would incorporate core body temperature, skin temperature and/or pulse rate. However, review of the current technologies at this time indicated that there were factors affecting the practicality and accuracy of these methods. It was therefore concluded that heat stress monitoring is the most practical method; this is based on 'look up' tables indicating safe working times for varying temperature, humidity and air velocity conditions. This lead to the decision taken by DMT to develop their own device to measure these parameters (CMD). CSRG assisted with respect to gas monitoring and it became apparent that GAUK had to allow data inputs to be a mixture of analogue and digital. Although the project setup allowed

for development of a specific biometric monitoring device, there was not the same remit regarding gas monitoring hence the m-Comm modifications needing to be adaptable methods potentially chosen in a working model specifically built to satisfy client needs. Specifications were made for recording levels of temperature, humidity, air flow, oxygen, carbon monoxide, carbon dioxide and methane.

Conclusions: The collaborative agreement on biometric and atmospheric measurement reached a consensus that had the endorsement of all the mines rescue organizations consulted. Deliverable D1.3 concludes Task 1.4.

1.1.5. *Results obtained of Task 1.5: Preliminary work bench for hydro-cutting technologies (ICOP, AITEMIN, KOMAG, GEOCONTROL, CSRG)*

The activity of ICOP and AITEMIN focused on the analysis of technological possibilities related to micro-tunnelling via hydro-cutting. Conceptual design activities for the workbench for testing water jet assisted rock cutting were carried out at the end of the period. They consisted mainly in the preparation of the executive design of the workbench, and included the scoping of suitable equipment for implementing it in that design.

After considering the two approaches by ICOP, (based on lathe machine and milling machine) it was decided that the test bench would be based on the lathe concept. As its main objective was testing the efficiency of the hydro-cutting technology on different types of rocks, the nozzles did not need to be rotating. Instead, a rotating base holding a rock block simulated the motion of the cutters relative to the rock. The water jet nozzles were fixed on the side of the cutters, simplifying the construction and operation of the test bench. A rotating high-pressure water distribution system was implemented in the demonstrator device. The final concept of the test bench was completed.
ICOP and AITEMIN, in consultations with GSRG and KOMAG, indicated that pure hydro-cutting will not be effective enough for the purpose of rescue actions. ICOP focused on analyses of mechanical cutting assisted by stream of water jet. Cutting of hard rock by a free-rolling cutter assisted by water jets showed significant reduction in the forces required to be applied to the cutter for given penetration increments. Pressures ranging from 5 to 40 MPa resulted in reductions in the forces acting on the cutter. The reduction in thrust force was found to be dependent on jet pressure: the

greater the pressure, the greater is the reduction of force. The most effective jet configuration for the reduction of cutter forces was found to be four coherent water jets, two positioned on each side of the cutter and directed at the arc of contact between the cutting edge and the rock. Jets impinging in the path of the cutter ahead of the rock-cutter interface also improve cutting performance by reducing the rolling force requirement, thus improving the mechanical cutting efficiency of the cutter.

To estimate the requirements for the high-pressure water jet system, and the results that could be expected, water-rock interaction was simulated by FEM software.

Conclusions:
Several methods of using the of water jets in different situations were reviewed in the literature to explore A detailed study on the addition of water jets to the cutting tools has shown a reduction of the required cutting force, either by weakening the rock or by improving the cutting conditions. Moreover, addition of water jets leads to an increase in tool life, to a reduction of machine vibration and of levels of generated dust together with a reduction of incendiary ignitions. T1.6 was completed.

1.2. WORKPACKAGE 2: DEVELOPMENT OF TECHNICAL DOCUMENTATION FOR RESCUE EQUIPMENT PROTOTYPES

1.2.1. Results obtained of task 2.1: Design studies of equipment (KOMAG, CSRG, AITEMIN, ICOP)

Komag developed 3D models of rescue conveyor with its shuttle platform, rescue support and air conditioner. Regarding air conditioner thermal and thermodynamic calculations to specify the parameters of conversion of cooling agent in the system: cooling unit – air cooler, were made. Heat exchange in the cooler was calculated, what enabled to determine the size of pipes in the cooler. In a result of T1.5, activity of AITEMIN was focused on a development of a concept design, flexible enough to be adapted for control of almost any final design of the tunnelling machine. One major constraint was the need to develop ATEX-certifiable control system, which imposed the use of ATEX-certified (or at least ATEX-certifiable) components.

Conclusions:
The design of the conveyor, rescue support and air-conditioner, demonstrator and experimental device by CSRG was verified. D2.1 and D2.2 was completed. AITEMIN analyzed the requirements for control system of microtunnelling machine, similar to µTBM and developed a suitable concept design of control panel.

1.2.2. Results obtained of task 2.2: Development of documentation of the rescue equipment (KOMAG, CSRG, AITEMIN, ICOP)

Design work on experimental device for rock fragmentation was continued on the basis of the results of tests that were carried out in Królowa Luiza mine in Zabrze. Proper depth of bolting was calculated. In the testing conditions, the best advantage was obtained at bolting depth of about 190 mm. KOMAG developed the technical documentation No. W20.270 of rescue conveyor. According to the assumptions, at first three conveyor troughs were manufactured according to a given design solution, so that the rescuers could test them and make comments. In the result of comments, some corrections were made in the documentation. Technical documentation No. W37.011 of HOR-01 hydraulic rescue support was developed by KOMAG according to the requirements and technical assumptions for newly designed rescue equipment developed in WP1. The documentations was made in CAD software programme.

ICOP developed the design of demonstrator equipped with double cutters. Double cutters are installed slidably in a special frame, so it is possible to change the radius of disks rotation on mined rock. The nozzles are directed to the point just ahead of contact between bit and rock.
AITEMIN has prepared updated documents on different devices selected for integration of µTBM control system.

Conclusions:
KOMAG finished the technical documentations of rescue equipment and advanced work on experimental device for rock fragmentation.

ICOP prepared the design of demonstrator and also the concept of hydro-cutting rescue machine to enable AITEMIN preparation of control system as it was planned within the project. Comprehensive analysis of cutting process as well as testing the different intensity of water jet streams used in rock cutting were done. Deliverable 2.4 was completed.

1.2.3. Results obtained of task 2.3: Virtual simulations of rescue action with use of models of rescue equipment (Geocontrol, KOMAG, AITEMIN)

Geocontrol focused on the development of virtual simulations of rescue action with models of rescue equipment prepared by KOMAG to present in an easy way the steps that have to be followed during the rescue action, with use of the rescue equipment. In the final version that has been carried out, miners represented in the simulation have been animated with motion capture technology, and the main movements in the scene action was achieved.

Conclusions:
The work developed in T.2.3, enable showing in a didactic form the processes of preparation of rescue devices by the final users. 3D modelling of rescue action adds realism to the displayed visualization, which results in its better understanding the process by the rescuers, who will use the equipment. All work has been developed and presented in D2.3.

1.2.4. Results obtained of task 2.4: Results and assessment of the workbench for hydro-cutting prototype (AITEMIN, ICOP)

ICOP focused on performing the FEM analysis to test different water jet flows and to understand their interaction with rock. The set-up of numerical model, definition of test matrix for virtual testing the different water jet configurations and numerical analyses able to predict the erosion process of water jet considering two types of rocks were determined.

The objective of these analyses was to set up a numerical model able to "capture" the erosion mechanism of the water jet and the influence of the water jet velocity (or pressure) on the different types of rock, characterised by an e elastic material model with implemented a strain-failure criterion.

Two types of rock were considered: material having a Young's modulus of 30 GPa and another material of elastic modulus of 70 GPa. Different speeds of water jets were considered, ranging from 400 m/s to 1000 m/s.

Conclusions**:**
Comprehensive analysis of cutting process as well as testing the different intensity of water jet streams used in rock cutting were finished. Deliverable 2.4 was achieved.

1.3. WORKPACKAGE 3: DESIGN OF PROTOTYPE INSTRUMENTATION AND COMMUNICATIONS SYSTEM FOR MEASURING BIOMETRIC AND ATMOSFERIC PARAMETERS

1.3.1. Results obtained of task 3.1: Development of biometric sensing and communication subsystems (CSRG, GAUK)

GAUK's collaboration with CSRG and DMT reinforced the requirement for monitoring the heat stress of individual mines rescue members as well as stated in Deliverables 1.4 and 1.5, the temperature, humidity and air flow as the most effective measure of currently employed worker for determination of the maximum operational or exposure time of rescuers. DMT worked on development of three-sensor device, which should be compatible with the Bluetooth wireless system of the m-Comm system. The biometric sensing and communication subsystems were developed by GAUK based on DMT's three sensor device for biometric monitoring and CSRG requirement for potentially different combinations of digital and analogue recording dependant on the number and type gas monitoring devices may be used. To this end, the wireless module interface was successfully developed with analogue and digital interface options for this purpose. In addition, GAUK demonstrated the combined voice and temperature and humidity monitoring system as an alternative. The temperature, humidity and possible others parameters will be essential in the wider field tests of the m-Comm system, particularly, in providing real display data at the 'fresh air' base.

Conclusions:
The biometric parameters and other sensors identified in Task 1.4 were interfaced with the m-Comm wireless module in a way that allowed for adaptability and be within the possibility of ATEX certification. To this end, the wireless module interface was successfully developed with analogue and digital interface options for this purpose.

1.3.2. Results obtained of task 3.2: Design of m-Comm data transfer and capture system (GAUK, DMT, Geocontrol)

The necessary electronic hardware and firmware were designed for initial data interfacing, data transmission, data capture and data storage. The work was broken down into 6 stages related to the different parts of the m-Comm system which required re-designing. This task was successfully completed. It was concluded that the successful completion of this design stage was partially related to the fact that this task ran alongside developing the production components. Where necessary the designs were modified to take into account unforeseen problems.
Conclusions:
The design of the m-Comm data transfer and capture system was successfully completed and documented in Deliverable 3.2*. It provides the following functions:*

- Biometric transponder data interfacing and initial processing to minimise data transmission

requirements
- Data transmission through the m-Comm system to fresh air base unit
- Data capture at fresh air base, storage and post processing for generation of an appropriate graphic display, warnings and alarms
- Data management for storage and archiving of measured parameters

1.3.3. Results obtained of task 3.3: Development of the measurement-system for environmental parameters (DMT)

DMT decided to develop the electronic system in two steps. At first, for quick and simple evaluation of practical handling as well as essential functions, the electronic-boards (PCBs) were developed and manufactured. This procedure gave the possibility to test the hitherto considered software intensively.

To meet the requirements of the ATEX directives, a 63 mA fuse was placed at the entry of power circuit, while further pre-resistors in the power-intensive elements underline the necessary considerations for secure ATEX-M1 applications in hazardous underground mining areas.

Conclusions: All electronic hardware of CMD unit was developed and constructed and all necessary software for the acquisition and transmission of measured data was realized. Also, the initial assumptions regarding the housing of the CMD unit was verified to make the housing more functional and handy.

1.3.4. Results obtained of task 3.4: Extension of virtual simulations of rescue actions by communication, measuring and data transfer systems (Geocontrol, GAUK, DMT)

After analyzing the most likely scenarios related with the INREQ project, in which accidents may occur, several rescue process were simulated taking a real mine as the simulation model. The simulation program, STEPs, was specially designed to simulate the movement of people both in normal conditions and during an evacuation in buildings, shopping centres, underground stations and tunnels. The default calculation bases of STEPS are taken from NFPA 130: Standard for Fixed Guideway Transit and Passenger Rail, but modifications on passengers' behaviour can be made during evacuation process.
STEPS allows creating a very precise 3D model from the scenario, where the evacuation takes place, besides the occupational load and the evacuation parameters.

Conclusions:
The various phases of the emergency situation, from the initial moment, where the miners are trapped on the front, until they reach emergency services was prepared.
By introducing the necessary time to announce alarm, alert the emergency services, arrival of rescue and all temporary dependent factors, it is possible to analyze rescue actions in different mines and simulate the theoretical time required.

1.4. WORKPACKAGE 4: MANUFACTURING OF PROTOTYPE EQUIPMENT FOR THE SYSTEM

1.4.1. Results obtained of task 4.1: Manufacturing of prototype and experimental equipment (KOMAG, AITEMIN, ICOP)

AITEMIN has analyzed the I/O needs of the control system, which required the prior identification of all the inputs and outputs of the existing µTBM, both digital and analogue, from the supplied information. The results of this analysis showed that the current control system uses 211 I/O lines: 90 digital inputs, 103 digital outputs and 18 analogue inputs
The proposed structure for the control system was prepared by AITEMIN basing on already certified hardware: FAR-V20 1A, MP40-RTU Ex and UCR-AV.
After AITEMIN's withdrawal from the project, KOMAG took over development of the control panel. (this additional KOMAG's work was finalized within the task 5.2)

KOMAG focused on manufacturing the prototypes. The prototypes were manufactured by external companies, which offered most advantageous conditions. The rescue support was manufactured by Herkules Company. The conveyor was manufactured by Artech in Rybnik. Elmech Kazeten Company from Czeladź was responsible for manufacture of air conditioner. The components of UDWR-1 experimental device for cutting the rocks were manufactured by Elektron company in Radzionków. The components of control panel was manufactured by Gabrypol company.

The water jet assisted cutting head demonstrator was manufactured by ICOP. The demonstrator had a fixed table (on which the rock block is positioned), rotating cutter head with two water jet nozzles and the hydraulic circuit of the unit and hydraulic pistons used to push the rotating system of cutters against the rock.

Conclusions:
KOMAG completed the production stage of the rescue prototypes. In the result of testing, minor changes were still possible within the next step. ICOP finished the demonstrator of the cutting head with water jet assistance and prepared it for the planned tests. Deliverables 4.1, 4.2 and 4.3 were completed.

1.4.2. Results obtained of task 4.2: Manufacture of prototype components of the system for data transfer and rescuer biometric measurement (GAUK)

A prototype m-Comm data communications system was successfully manufactured. The work was broken down into 6 stages and individually each stages' component's were tested to ensure that the system would be operational as a whole.

Conclusions:
The prototype components were been successfully developed and manufactured in T4.2, and described in Deliverable 4.4. Laboratory's tests of the system are described in T 5.1.

1.4.3. Results obtained of task 4.3 : Manufacture of prototype instrumentation for measuring mine atmosphere and system for data transfer (DMT, GAUK)

In the result of suggestions in T3.3, DMT had to reworked the first prototype of CMD in T4.3. The most significant change to the housing geometry was necessary with regard to the chosen anemometer, which should be integrated with the housing protecting against ingress of dust and against mechanical damages. To use the air-speed sensor, a telescopic system was used to increase the measurement accuracy. For quick and reproducible measurement of temperature and humidity, a more battery-sparing fan was selected. This fan offers the possibility to measure its rotational speed that can then be used to control this speed by software.

Conclusions:
DMT designed, developed and manufactured two different prototypes of CMD in two successive steps. While the first one was built for all necessary testing the next one included the changes resulted from testing the first one. Exchange of information and discussions with GAUK concerning the transfer of measured climate parameters via "m-Comm" was converted into the concrete software.

1.5. WORKPACKAGE 5: TESTING OF SYSTEM COMPONENTS IN THE LABORATORY AND IN SITU TESTS

1.5.1. Results obtained of task 5.1 Laboratory tests of data monitoring and transfer system (GAUK, DMT, CSRG)

Laboratory tests were undertaken without the DMT device and proved that the whole system was working together including the display of transmitted data within the developed software. It was concluded that the whole system's functionality was associated with the design and manufacture process, breaking this down into individual design and test stages. Further laboratory testing then took place with the DMT device. These were successful following consideration of physical issues voltage level, conversion, aerial location and link indicator, LED, location. These include: improve through data rates, conduct more sensor input tests, further development on base unit data output interfaces, refinements on the current data display screen for the 'fresh air' PC. Next to the tests during the development work, DMT has developed a useful calibration test for the selected anemometer. Such (quality managing) adjustment procedures are a prerequisite for a precise monitoring of the measured climate parameters.

Conclusions:
The laboratory tests of m-Comm system with the DMT device were successful following consideration of physical issues voltage level, conversion, aerial location and link indicator, LED, location. The task was completed and the deliverable 5.1 was prepared.

1.5.2. Results obtained of task 5.2: Laboratory tests of prototypes of rescue devices and experimental devices (KOMAG, CSRG, AITEMIN, ICOP)

The conveyor with platform, roadway support, fan section of air conditioner and device for cutting the rock were initially tested at test stands in KOMAG. Representatives of CSRG were invited for the tests to be acquainted with the devices before sending them for tests to CSRG.

Laboratory tests with a simplified prototype of the Control System were initiated by AITEMIN. Unfortunately, AITEMIN withdrawn from the project at the end of 2014. Coordinator applied for extending the time for project realization by 3 months and the Commission agreed for it. This allowed KOMAG for continuation the AITEMIN's work regarding the control panel. Within this task, KOMAG developed the control panel instead of AITEMIN and conducted the tests of it with positive results.

Conclusions:
The rescue devices (i.e. conveyer, support and air conditioner) were tested in KOMAG and the results of tests were positive. ICOP tested positively the demonstrator. The work on the final control panel was completed by KOMAG after AITEMIN's withdrawal**.** The deliverable 5.2 was completed.

1.5.3. Results obtained of task 5.3: Field tests of prototype rescue devices (KOMAG, AITEMIN, ICOP, CSRG)

The experimental UDWR-1 device for rock cutting was tested in the working of Królowa Luiza mine. Tearing of rock solid started after suspension and fixation of bolt in RCH-606 single-acting cylinder of UDWR-1 device. The bolt was fixed after making the borehole and its insertion to the borehole. Fixation of bolts was possible due to the drifter drill equipped with a proper wrench (recommended by the manufacturer of bolts) fixed in the drill handle. Every time, after fixing the bolt the process of tearing the rock solid out was realized. During the tests, the bolts were fixed at different depth and the measurements were recorded.

Four hydraulic legs (two SHR-700 legs and two SHR-960 legs), three roof beams and two stabilization systems were used for testing the roadway support. The tests were realized in the training working at CSRG in Bytom.

The conveyor with platform was tested in training room at CSRG. The need for making the corrections in conveyor turntable was indicated. The corrections were made within WP6.

ICOP performed the field test at its premises. Aim of the tests was to check how assistance of water jet supports rock-cutting process. Two blocks one made of granite and second made of concrete were prepared for testing.

Conclusions:
Rescue support, conveyer and experimental device for low energy rock cutting were tested by KOMAG and CSRG. Some modifications regarding conveyor and experimental device were recommended. ICOP performed the tests using two types of rock blocks. The results confirmed greater effectiveness of the cutting method with water jet support. The deliverable 5.3 was completed.

1.5.4. Results obtained of task 5.4: Field tests of prototype of rescue devices and communication system in mine training workings (CSRG, KOMAG, GAUK, DMT)

The field trials allowed further assessment of the system as a whole in order to determine any further improvements and refinements that were necessary or desirable before the end of the project. The field trials demonstrated that two separate data recording wireless links were able to successfully record and send information back to the base unit and portable PC. One of main requirements regarding the Mk 3 m-Comm system was that the voice function should not be affected in any way; for obvious safety reasons voice traffic must be available when commanded. This was repeatedly tested and no loss of voice connection was witnessed.

Conclusions:
Usefulness of the devices developed by KOMAG was confirmed. GAUK's m-Comm and DMT's CMD were also positively tested by the rescuers. These field trials allowed further assessment of the system in order to specify any further improvements..

1.6. WORKPACKAGE 6: APLICATIONS FOR CERTIFICATION AND APPROVAL FOR USE IN UNDERGROUND COAL MINES

Task 6.1: Intrinsic safety approval of the electronic sub-systems (GAUK, DMT, KOMAG)

Partners carried out the tests for conformity of each component to the requirements of the relevant Directives that are in force. GAUK prepared the ATEX and IECEx application to conform to the specifications of the UK ATEX and IECEx directives against which they were to be evaluated. This included the preparation of detailed drawings of the modified circuitry.

Conclusions:
KOMAG finished preparations for rescue equipment and control panel.
DMT- finished all preparations regarding its CMD unit. GAUK –prepared the ATEX and IECEx application to conform to the specifications of the UK ATEX and IECEx directives against which they were to be evaluated. The deliverable 6.1 as report was completed.

Task 6.2: ATEX, IECEx and mining company approvals of components (KOMAG, GAUK, DMT)

KOMAG positively certified three rescue devices and components of control system for cutting machine of principle of operation similar to µTBM.
DMT completed certification of CMD device.
GAUK planned to submit the ATEX and IECEx application to the relevant body in the UK which is SIRA Certification Service based in Chester. However, this was not possible within the timeframe of the project as preparation of the application was lengthy due to the complex nature of the changes and the will to make sure that the application was successful at the first attempt and in part slowed by the sale of GAUK instrumentation department to Trolex Ltd. Trolex Ltd. Now it is planned to submit the application as soon as practicable

Conclusions:
KOMAG obtained the ATEX certificates for rescue conveyor, support, air conditioner and control panel. DMT obtained ATEX certification for its CMD unit. These documents approve using these devices in mines during rescue actions. It was not possible to submit GAUK device for ATEX and IECEx certification within the timeframe of the project. Deliverables D6.2, D6.3 and D6.4 were completed

1.7. USEFULNESS, CONCLUSIONS AND POSSIBLE APPLICATIONS AND PATENTS

Rescue conveyor and rescue support designed by KOMAG within the INREQ project are lighter than such devices used so far by rescuers besides they have better technical parameters and new functionalities. Rescuers found the auxiliary platform moving along the conveyors route as very useful speeding up development of rescue tunnel in debris area. Movable air-conditioner, which was fully approved by rescuers, is a newly designed device. These devices are ready to be used by rescuers during rescue actions. These devices can also be used for training the rescuers. While the experimental device for development of tunnels in solid rock was not positively verified despite the first success. KOMAG still works on this technology and it is the subject of patent application submitted in the Patent Office.

MK3 m-Comm communication system developed by GAUK is useful and requires certification before using it in mine underground. CMD developed by DMT can be used as the independent device as well as it can be used together with MK3 m-Comm.

Demonstrator developed by ICOP was used in very helpful and important tests on hydro-cutting technology. This technology can be useful in µTBM devices. KOMAG is ready for collaboration and offers the control panel, which has the required certificates for using it in a potentially explosive atmosphere

2. <u>SCIENTIC AND TECHNICAL DESCRIPTION OF THE RESULTS</u>

2.1. OBJECTIVES OF THE PROJECT

The INREQ project was aimed at achieving a comprehensive improvement in rescue team safety, work comfort and effectiveness. The project research methodology was involved the research, development and significant enhancement of selected rescue equipment, and providing a remote real time hazard monitoring capacity for individual biometrical parameters of rescuers together with key climatic parameters in the workings where rescue action was carried out. The development of the following dedicated rescue equipment was planned in the project:

- a lightweight rescue conveyor complete with a shuttle palette transport arrangement,
- a lightweight support to aid the driving of rescue tunnels,
- a lightweight air conditioning system to supply cooled air to the rescuers' workplace,
- a rescue tunnelling device based on hydro cutting technology,
- a rock fragmentation experimental device with low specific energy requirement,

The development of methods for monitoring physiological and local climatic parameters was addressed the following project objectives:

- providing personal biometric data from the forward rescue team,
- reducing risks of thermal strain, and
- measuring environmental conditions in the forward rescue team's working area.

Within the above physiological and climatic range of the project, two electronic devices were planned to be realized in close cooperation by GAUK and DMT.

2.2. DESCRIPTION OF ACTIVITIES AND DISCUSSION

This part of the Report presents the activity on each of the developed devices sequentially and virtual simulation that had helped in the development of devices with an indication of progress within the WPs and tasks. The order of the presentation is as follows:

- a lightweight rescue conveyor complete with a shuttle palette transport arrangement,
- a lightweight support to aid the driving of rescue tunnels,
- a lightweight air conditioning system to supply cooled air to the rescuers' workplace,
- a rescue tunnelling demonstrator based on hydro cutting technology,
- a rock fragmentation experimental device with low specific energy requirement,
- a communication system
- CMD unit

2.2.1. Lightweight rescue conveyor complete with a shuttle transportation platform

The work on this equipment was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Tasks 1.1, 1.2 of WP1
Task 2.2 of WP2
Task 4.1 of WP4
Task 5.3 of WP5
Task 6.2 of WP6

Task 1.1 Determination of assumptions for prototype and experimental rescue equipment

CSRG in cooperation with KOMAG has defined the parameters and requirements for the light rescue conveyer with a mobile shuttle transport pallet:

- conveyor's length – minimum 30 running metres;
- conveyor's trough should have the following dimensions: length – 1000 mm and 500 mm, width – 350 mm
- one-thread leading chain 14 mm
- a possibility of transport platform movement in two directions (in the case of technical difficulties a one-direction movement has been taken into consideration), the platform is among others designed to transport troughs, parts of rescue support, tools;
- troughs joined by means of wedges or quick connects, enabling a change of direction by 5° on each trough;
- it has been initially established that the medium to supply the conveyor will be a hydraulic drive; as the project advances, an electric drive will also be taken into consideration;
- the output depend on the conveyor's length and the type of drive applied;
- in order to simplify the conveyor's installation, the marking of the bottom and top of particular troughs has been taken into consideration;

- the whole route of the conveyor will be extended by minimum 3 troughs (3 running metres);

Specialists from KOMAG have developed special, effective technology for extension of the conveyor by 3 m for every step of extension, during development of rescue tunnel with use of shuttle platform to transport indispensable equipment – support legs, canopies, troughs and chain. The technology was briefly presented in the first Annual Report

Task 1.2 Initial 3D modelling of equipment

According to the assumptions developed in T1.1, modelling the conveyor in Inventor software programme was performed to get useful tools for development of technical documentations. Before that, important structural components were verified by the FEM method. Models of each conveyor subassembly enables among others carrying out FEM analyses, virtual assembly of conveyor components, simulation of shuttle platform travel and relative movement of the route components. FEM analyses of conveyor trough were made by Geocontrol and KOMAG (Fig.1).

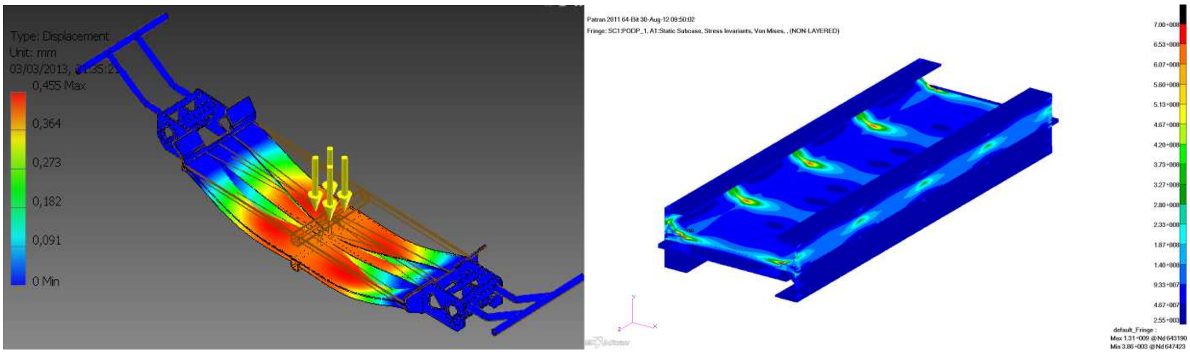

Fig.1: FEM analyses of the platform and the trough (conveyor pan) – by Geocontrol

The model of the conveyer and it's shuttle platform is shown in Fig.2. Shuttle platform is driven by flight chain. It is universal and it can transport support's legs, canopies, conveyor extension three troughs as well as it can be used to move rescuer or injured person in a horizontal position. Fig.3. presents 3D models of the conveyors drive, return end and the chain with the scraper.

Fig.2: 3D model of the rescue conveyer with the shuttle platform and the new version of trough (by KOMAG)

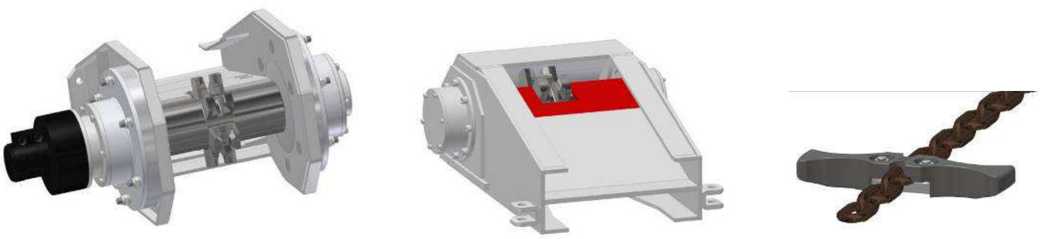

Fig.3: 3D model of the conveyer drive (on the left) and return (middle) and the scraper with chain (on the right)

Task 2.1 Design studies of equipment prototypes
Troughs of the conveyor were checked regarding the possibility to bend both in vertical and horizontal plane to allow the driven rescue tunnel to pass by the obstacles that is why generally the conveyor route is not rectilinear (Fig.4. , 5.)

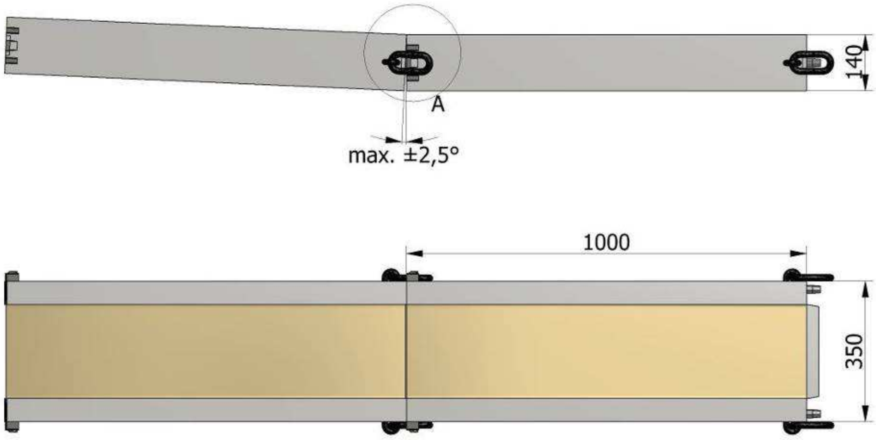

Fig. 4: Range of possible deflection of troughs in vertical plane

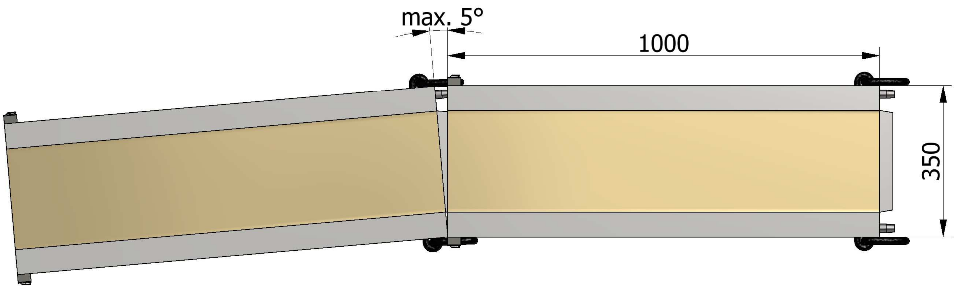

Fig.5: Range of possible deflection of troughs in horizontal plane

Trough version with magnetic lock of adhesion force 40N showed in Fig.6. was developed.

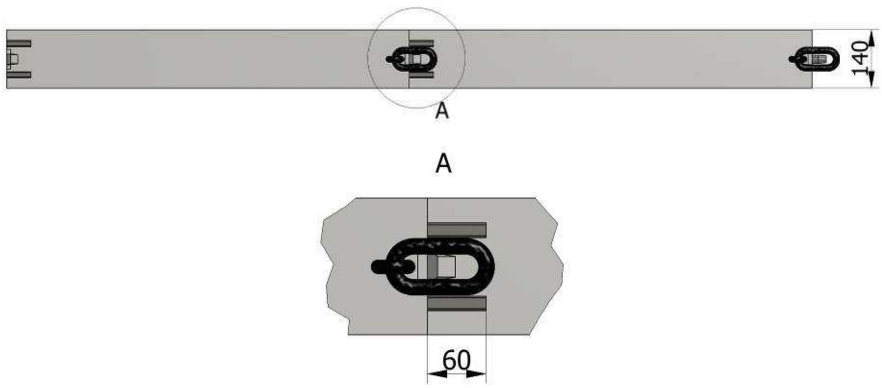

Fig.6: Troughs with magnetic lock of 40N force

In a result of consultations with CSRG specialists, it was turned out that shuttle platform requires the emergency device, which would stop the platform by the travelling rescuer at any place on the track. In this situation a solution, which would enable to stop the platform at any place, independently from the operating chain, was searched. It was necessary to develop articulated coupler of the platform instead of the previous fixed one. The platform (Fig.7.) was equipped with handles helping the rescuers to keep balance on the platform.

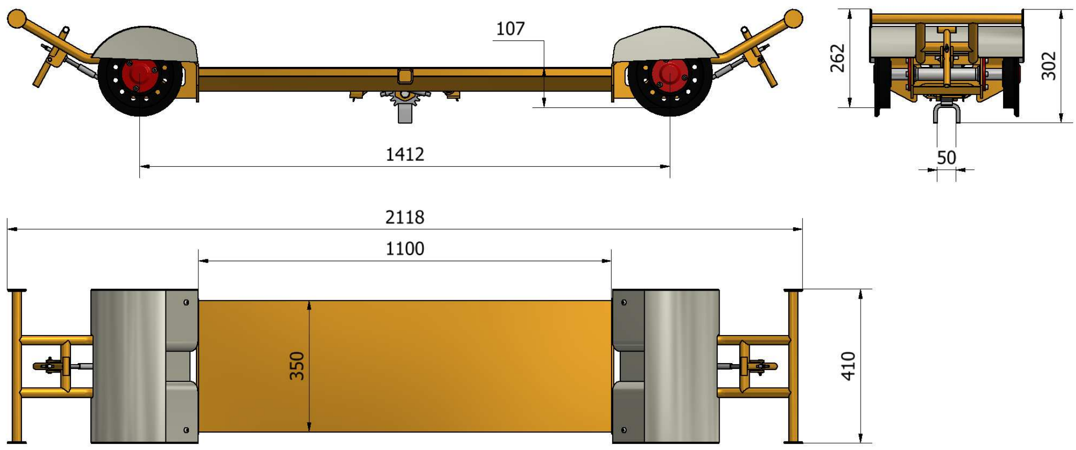

Fig.7: New design of auxiliary platform with articulated coupler

The principle of operation of articulated coupler is explained in Fig.8. (on the left). The coupler is kept in its operational position (vertical position) by a short rack. The rack is blocked on both sides.

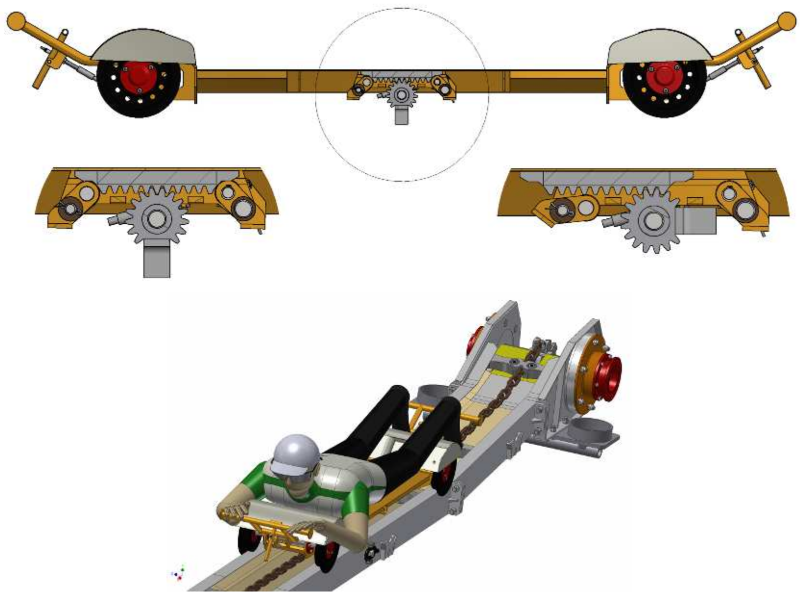

Fig.8: Principle of operations of the platform coupler and rescuer's position on the platform

When the rescuer has to use the platform to travel, he takes a lying position (on the right) and put hands on handles. The rescuer should always move with his head directed towards the travel direction to observe the route ahead. In the case of any danger he should release the blockade to stop the platform.

Task 2.2: Development of documentation of the rescue equipment

CSRG played an advisory role in this Task. Technical documentation No. W20.270 of the rescue conveyor was developed by KOMAG. The documentation was made in CAD software programme. A lot of attention was paid to the connections of troughs, and the protection of connecting links was changed many times upon the request of CSRG. In the result of testing, the second version of quick-connections was developed in 2013. It was found that the force of link adhesion is still inefficient. Due to this a compromise solution of protection for the connecting link was developed. Articulated arm, pivotally installed to the lower part of trough profile and maintained by magnet in the upper part, was used. Due to design solution and frontal adhesion of metal sheet of arm to the magnet, the force protecting the connecting link at present is five times higher than it was in the previous solution. In the result of consultation on auxiliary shuttle platform, CSRG specialists indicated the necessity to equip the platform with handles and belts for load fixation – the method for stabilization of loads with use of belts fixed to the handles is presented in Fig. 9. In the Fig.10. drive of the conveyor and return end are shown.

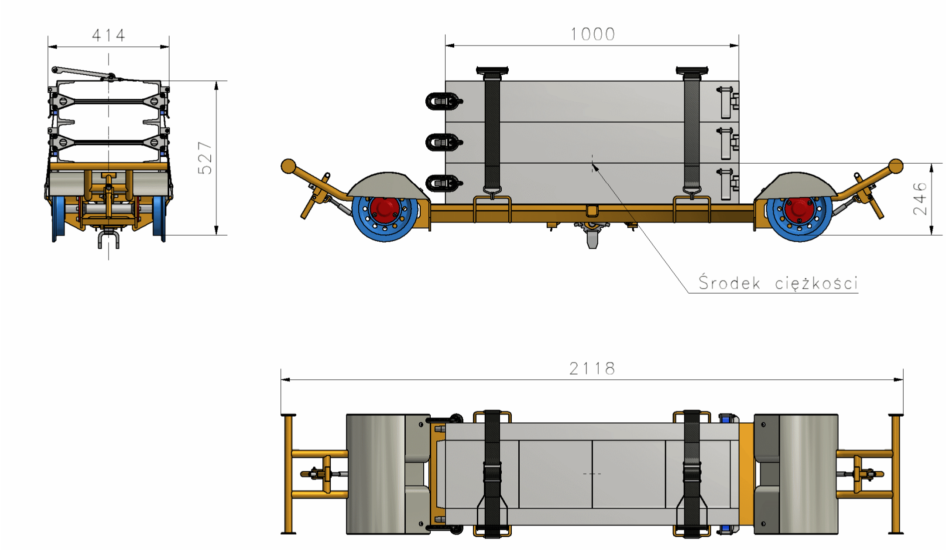

Fig.9: Analysis of the conditions of stability platform when troughs are loaded on top of each other.

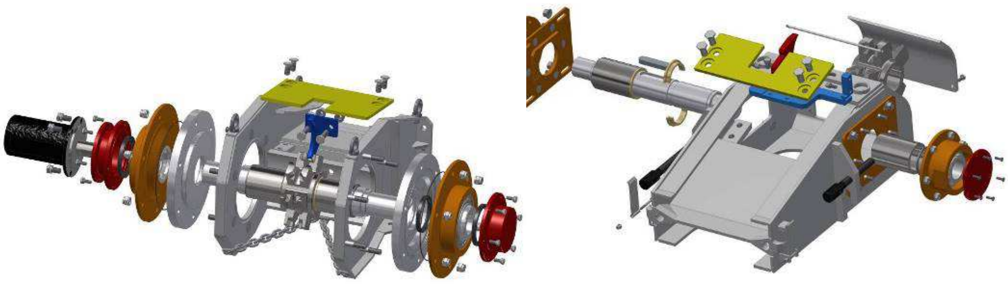

Fig.10: Detailed drawings of the drive (right) and the return end (left) of the conveyer

WP4: manufacturing of prototype equipment for the system

Task 4.1 Manufacturing of prototype and experimental equipment

Within the task KOMAG manufactured the prototype of the rescue conveyor and its shuttle platform. It was very important to deliver the first conveyor troughs to CSRG to test them. According to the assumptions, at first three conveyor troughs were manufactured according to a given design solution, so that the rescuers could test them and make comments. In the result of the comments some corrections were made in the documentation and the next three troughs were manufactured to be tested. Comparison strength tests were carried out on the press prior to delivery of the troughs to CSRG. New design solution of troughs turned out to be more resistant to loads, and at the same time it is lighter. Fig.11. shows the comparative tests of the troughs.

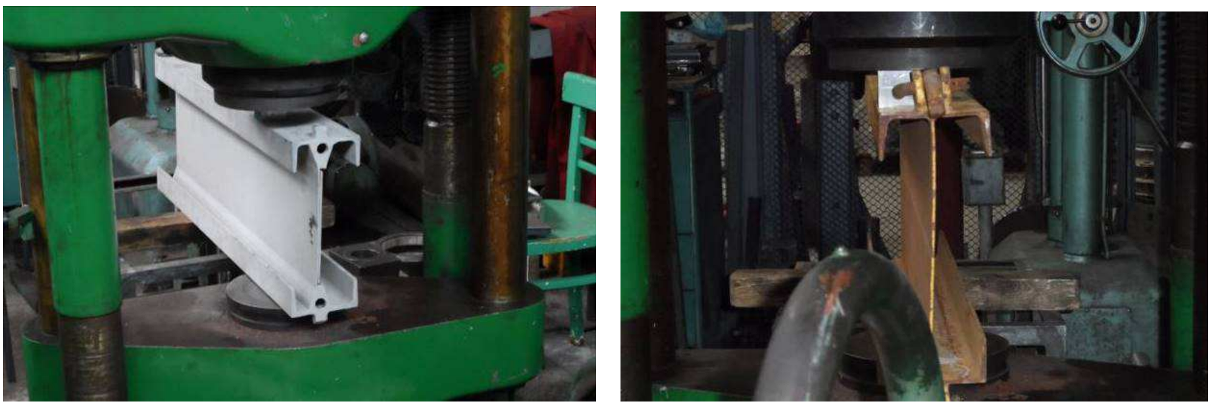

Fig.11: Comparison strength tests of the new through (left side) and former trough (right side)

The conveyor was manufactured by Artech company in Rybnik. The basic components of the conveyor are presented in Fig.12 and Fig.13.


Fig.12: The new troughs (on the left) and conveyors drive (on the right)

Fig.13: The shuttle platform of the conveyor

Task 5.3 Field tests of prototype rescue devices

The conveyor with platform was tested in training room at CSRG – Fig.14. The need for making the corrections in conveyor turntable was indicated. The corrections were planned to be made within WP6.


Fig. 14: Tests of the conveyor and its shuttle platform at CSRG

Task 6.2 ATEX, IECEx and mining company approvals of components

All documents necessary to obtain the certificate were developed within WP6. The manual is one of them and its first page is presented in Fig.15. The certificate of conformity No. TEST/20/CZ/2015 which authorizes the conveyor for operation in mine undergrounds in rooms threatened by explosion hazard, was issued in a result of certification of this conveyor carried out by the TEST Company.

INSTYTUT TECHNIKI GÓRNICZEJ

44-101 Gliwice, ul. Pszczyńska 37
tel. 32 2374100, fax: 32 2310843

INSTRUKCJA

Przenośnik ratowniczy zgrzebłowy
z platformą pomocniczą

W20.270IOR

wydanie 1

GLIWICE, styczeń 2015

Instrukcja oryginalna

DOKUMENT PRZEZNACZONY JEST WYŁĄCZNIE DLA POTRZEB UŻYTKOWNIKA I NIE MOŻE BYĆ BEZ PISEMNEJ ZGODY PRODUCENTA I/LUB KOMAG-u WYKORZYSTYWANY W KRAJU I ZA GRANICĄ

Jednostka Opiniująca,
Atestująca i Certyfikująca Wyroby
TEST Sp. z o.o.

AC 149

CERTYFIKAT ZGODNOŚCI
Nr TEST/20/CZ/2015

(1) Nazwa i adres producenta:
ARTECH RYBNIK Sp. z o.o.
ul. Wodzisławska 175 B
44-218 Rybnik

(2) Nazwa wyrobu: **Przenośnik ratowniczy zgrzebłowy z platformą pomocniczą**

(3) Prawo do wykorzystywania certyfikatu dotyczy wyłącznie egzemplarzy wyrobów odpowiadających wymaganiom dokumentów normatywnych stanowiących podstawę wydania certyfikatu oraz wykonanych zgodnie z przedstawioną do certyfikacji dokumentacją techniczną wyrobu, zgodnie z Programem certyfikacji PR-II.

(4) Wyniki przeprowadzonych badań wyrobu zostały wyszczególnione w Sprawozdaniu z badań Nr LT/088/2015 z 28.08.2015 r.

(5) Ocenę, wykaz dokumentów i sprawozdań z badań, stanowiących podstawę wydania niniejszego certyfikatu, zawarto w poufnym raporcie z oceny wyrobu Nr TEST/RW/48/CZ/15/ZM/2015 z dnia 28.09.2015 r.

(6) Niniejszy Certyfikat może być rozpowszechniany tylko w formie niezmienionej. Częściowe odtwarzanie i rozpowszechnianie niniejszego certyfikatu jest niedozwolone.

(7) Certyfikat zachowuje ważność w okresie
od 30 września 2015 r. do 29 września 2018 r.

Siemianowice Śl., dnia 30 września 2015 r.

JOACW TEST Sp. z o.o. ul. Wyzwolenia 14, 41-103 Siemianowice Śląskie
Tel./Fax. +48 32 7308200, www.joac-test.pl

Fig.15: Title page of the conveyor manual and certificate of the conveyor issued by TEST

2.2.2. Rescue support

The work on this equipment was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Task 1.1 of WP1
Task 2.2 of WP2
Task 4.1 of WP4
Task 5.3 of WP5
Tasks 6.1, 6.2 of WP6

Task 1.1 Determination of assumptions for prototype and experimental rescue equipment

Guidelines regarding the roof bar beam load in calculations and in the process of certification testing was defined. The roof bar supported on both sides will be loaded by three forces of the total value of these forces results from the bearing capacity of props and reaches 600 kN.

Protection of roof to ensure the possibly highest safety of rescuers and injured people is the main task of rescue tunnel support. Design of the rescue support meets the following requirements:

- steel canopy and hydraulic legs are of high strength,
- low weight enables manual assembly in difficult conditions,
- the leg has its own hydraulic system, to adjust its height to the needs, as well as it can be used as individual spacing equipment.

Guidelines regarding the canopy load in calculations and in the process of certification testing were defined. The canopy will be loaded in three points. The total value of the forces results from the load-bearing capacity of legs and reaches 600 kN.
Task 1.2 Initial 3D modelling of equipment

In the result of realization of the task 1.2 , the concept of the hydraulic legs with internal pump was developed – Fig.16.

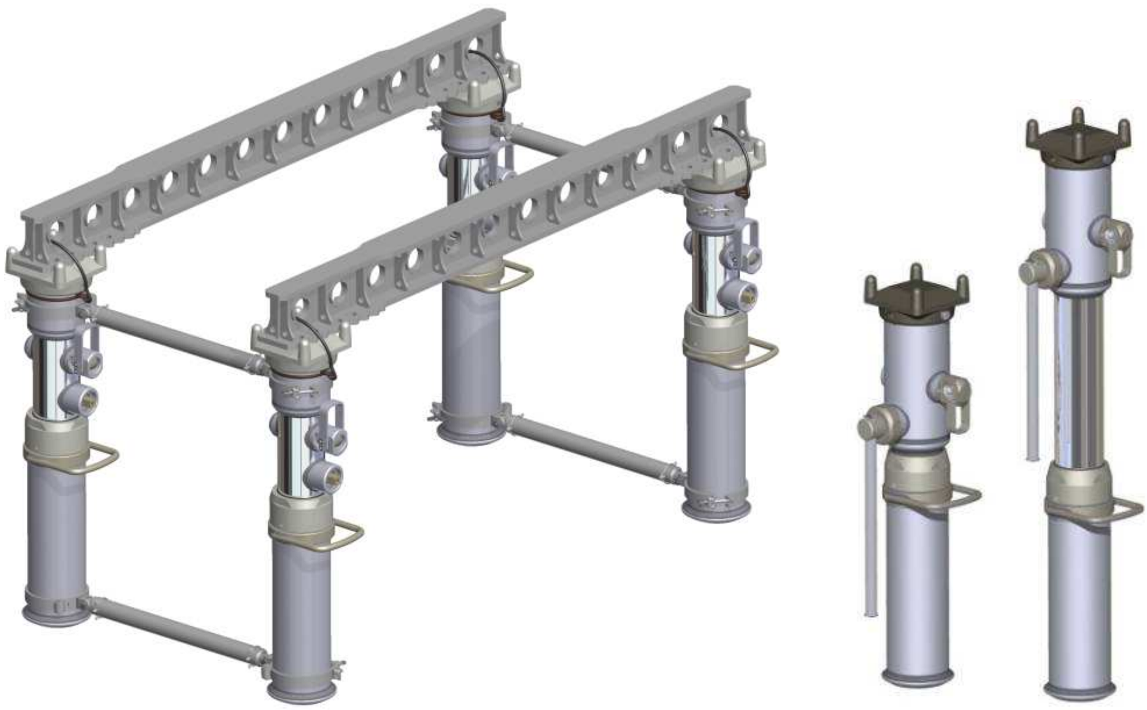

Fig.16: 3D model of rescue support (on the left) and its hydraulic legs (on the right)

Task 2.2: Development of documentation of the rescue equipment

In the result of realization of the task, the design of the hydraulic legs with internal pump was developed. Modification of the overflow valve of the legs was realized – showed on Fig.17.

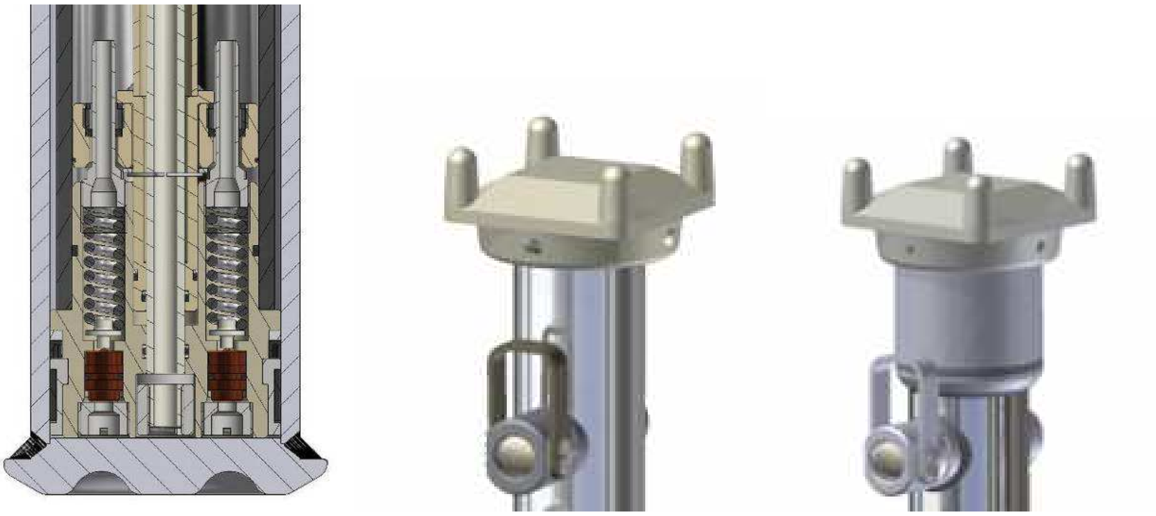

Fig.17: Modification of the overflow valve (left) and modified prop of the leg – the right prop is the final

Overflow valves, which limit increase of working medium – oil – in the case of static and dynamic load, are installed in the leg's piston. In the case of dynamic load, stream of oil flowing through overflow valves fills the space between leg's main piston and piston of first stage internal pump. Due to small volume between the abovementioned pistons, the piston of first stage internal pump can be damaged. To avoid this, additional overflow channels going through the piston of internal pump were installed, so the oil will be transported directly to the oil tank.
When analyzing the volume of oil required for setting the SHR-700 leg to maximal height, it appeared that free volume inside the prop is not enough and it was necessary to add another tank to the design. Geometrical models of leg prop before and after modification, are given in Fig.17.

Design studies of two types of hydraulic legs were made. Fig.18. shows technical parameters of the hydraulic leg SHR-700 and Fig.19. the hydraulic leg SHR 960.

Technical characteristics of SHR-700 hydraulic leg

Parameter	**Value**	**Unit**
Minimal length	700	mm
Maximal length	1000	mm
Initial bearing capacity	150	kN
Rated bearing capacity	300	kN
Hydraulic pitch	300	mm
Weight	30.0	kg

Fig. 18: Technical parameters of the hydraulic legs type SHR-700

Technical characteristics of SHR-960 hydraulic leg

Parameter	**Value**	**Unit**
Minimal length	960	mm
Maximal length	1300	mm
Initial bearing capacity	150	kN
Rated bearing capacity	300	kN
Hydraulic pitch	340	mm
Weight	35.0	kg

Fig.19: Technical parameters of the hydraulic legs type SHR-960

In Fig.20. geometric model of telescope consisting of external pipe - body (1), connectors (2, 3) and pins (5) blocking the connectors is shown. Telescopic structure enables meeting the subdivision length of neighbouring frames of rescue support, required by the project assumptions.

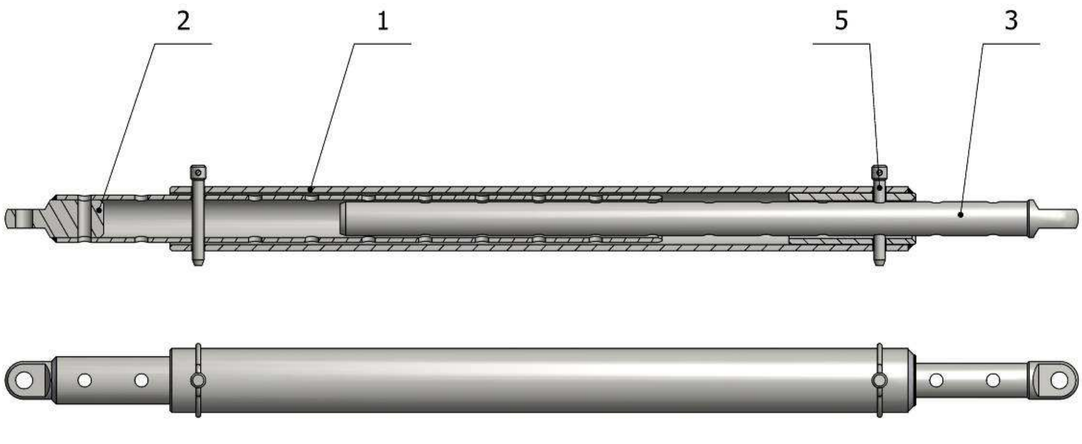

Fig. 20: Geometric model of stabilizer telescope

In the case of design studies the support protecting passages through voids, the canopy beams should be additionally secured. Transverse stabilization of canopy beam is ensured by properly profiled shape of lower metal sheet of canopy adapted to the shape of leg top.

Task 4.1 Manufacturing of prototype and experimental equipment

The prototype was manufactured by Herkules, the external company, who offered most favourable conditions. Fig. 21 presents two hydraulic legs and the canopy creating so called single doorposts of the rescue support.

Fig.21. Hydraulic legs and canopy made by Herkules company

Task 5.3: Field tests of prototype rescue devices

Four hydraulic legs (two SHR-700 legs and two SHR-960 legs), three roof beams and two stabilization systems were used for testing the roadway support. The tests were realized in the training working at CSRG in Bytom. Frame installed in training working is presented in Fig. 22.

Fig. 22: Field tests of HOR-01 roadway support

Task 6.1: Intrinsic safety approval of the electronic sub-systems

Tests of rescue support were ordered. Stand tests of SHR-700 and SHR-960 hydraulic legs were carried out in the Technical Laboratory in Opava, Czech Republic (Fig.23 and 24 according to the requirements of the PN-G-15536:2013 Standard "Mine individual support – centrally supplied hydraulic legs".

Fig.23: Static stand tests of the leg

Fig. 24: Dynamic stand tests of the leg

Instructions for use of devices of rescue support, conveyor with platform and air conditioner were prepared within T6.1. In the result of the tests carried out at CSRG (T5.4) it appeared that some changes in sub-system of conveyor drive were required.

Task 6.2: ATEX, IECEx and mining company approvals of components

KOMAG has positively completed certification process for the rescue support – Fig. 25.

Jednostka Opiniująca,
Atestująca i Certyfikująca Wyroby
TEST Sp. z o.o.

AC 149

CERTYFIKAT ZGODNOŚCI
Nr TEST/17/CZ/2014

(1) Nazwa i adres wnioskodawcy/dystrybutora:
Herkules Sp. z o.o.
ul. Strzelców Bytomskich 8/9
44-280 Rydułtowy

(2) Nazwa i adres producenta:
Herkules Sp. z o.o.
ul. Strzelców Bytomskich 8/9
44-280 Rydułtowy

(3) Nazwa wyrobu: **Hydrauliczna obudowa ratownicza HOR-01**

(4) Typ: **HOR-01**

(5) Wyrób spełnia wymagania norm:

PN-EN ISO 12100: 2012 (EN ISO 12100: 2010)
PN-G-15536: 2013
PN-EN ISO 4413: 2011 (EN ISO 4413:2010)
PN-EN 13463-1: 2010 (EN 13463-1: 2009)
PN-EN 1710+A1:2010/AC:2011 (EN 1710:2005+A1:2008)
PN-EN 1127-2+A1: 2010 (EN 1127-2: 2002+A1: 2008)

(6) Ww. wyrób został określony w załączniku. Załącznik zawiera wykaz uzgodnionych dokumentów, przeprowadzonych badań oraz może także zawierać ewentualne uzupełnienia do niniejszego certyfikatu.

(7) Niniejszy certyfikat obowiązuje w całości z załącznikiem.

(8) Certyfikat wydano zgodnie z systemem certyfikacji 3.

(9) Prawo do wykorzystywania certyfikatu dotyczy wyłącznie egzemplarzy wyrobów odpowiadających certyfikowanej próbce wyrobu oraz przytoczonych powyżej dokumentów normatywnych i posiadających identyczne właściwości (parametry) jak przedstawiony do badań wzór.

(10) Certyfikat zachowuje ważność: **od 30 września 2014 r. do 29 września 2017 r.**

V-ce Prezes Zarządu
ds. Certyfikacji
JEDNOSTKI OPINIUJĄCEJ, ATESTUJĄCEJ
I CERTYFIKUJĄCEJ WYROBY
TEST Sp. z o.o.
Ireneusz Adamus

Siemianowice Śl., dnia 30 września 2014 r.

JOAiCW TEST Sp. z o.o. ul. Wyzwolenia 14, 41-103 Siemianowice Śląskie
Tel./Fax. +48 32 7308200, www.joac-test.pl

Jednostka Opiniująca,
Atestująca i Certyfikująca Wyroby
TEST Sp. z o.o.

AC 149

(11) **Załącznik**

(12) **CERTYFIKAT ZGONOŚCI Nr TEST/17/CZ/2014**

(13) Opis i przeznaczenie:
Hydrauliczna obudowa ratownicza HOR-01 jest urządzeniem grupy I kategorii M2, zgodnie z Dyrektywą 94/9/WE (ATEX).
Jest indywidualną obudową prostą, przeznaczoną do zabudowy wyrobisk górniczych, w szczególności podczas prowadzenia prac ratowniczych.
Przeznaczona jest do użytkowania w podziemnych zakładach górniczych w pokładach zagrożonych i niezagrożonych tąpaniami w polach niemetanowych i metanowych w wyrobiskach zaliczonych do stopnia „a", „b" lub „c" niebezpieczeństwa wybuchu metanu oraz w wyrobiskach zaliczonych do klasy A lub B zagrożenia wybuchem pyłu węglowego.

(14) Parametry techniczne deklarowane przez producenta:

Parametr	Wartość	Jednostka
Minimalna wysokość: - ze stojakami SHR-700 - ze stojakami SHR-960	800 1060	mm
Maksymalna wysokość: - ze stojakami SHR-700 - ze stojakami SHR-960	1100 1400	mm
Długość stropnicy	1300	mm
Rozstaw stojaków (osi stojaków): - minimalna - maksymalna	720 1140	mm
Podporność wstępna	300	kN
Podporność robocza	600	kN
Ciśnienie robocze stojaka	47	MPa
Masa stropnicy	20	kg
Masa obudowy: - ze stojakami SHR-700 - ze stojakami SHR-960	93 103	kg
Medium robocze	HYDROMIL SUPER L-HV 32, HYDRAX HLP 32,	
Temperatura stosowania (otoczenia)	od - 15 do + 50	°C

V-ce Prezes Zarządu
ds. Certyfikacji
JEDNOSTKI OPINIUJĄCEJ, ATESTUJĄCEJ
I CERTYFIKUJĄCEJ WYROBY
TEST Sp. z o.o.
Ireneusz Adamus

TEST/17 /CZ/2014 Siemianowice Śl., dnia 30 września 2014 r. Strona 2 z 3

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Fig.25: Certificate for conformity of HOR-01 rescue support, confirms that product is classified for group I category M2 according to 94/9/WE Directive (ATEX)

2.2.3. Air conditioner

The work on air conditioner was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Tasks 1.1, 1.2 of WP1
Task 2.2 of WP2
Task 4.1 of WP4
Task 5.3 of WP5
Task 6.2 of WP6

Task 1.1 Determination of assumptions for prototype and experimental rescue equipment

CSRG in cooperation with KOMAG has defined the parameters and requirements for the air conditioner as follows:

Lightweight air-conditioner for improving the work conditions:

- type of ventilation – forced ventilation,
- nominal diameter of the fan: 400 mm,
- internal diameter of the air-duct supplying the air to a rescue excavation: 120 mm, external diameter ca 140 mm (thickness of offered walls – ca 10 mm),
- output up to 30 m^3/min,
- a possibility of connecting flexible air-ducts having a diameter of 120 mm or air-ducts having larger diameters – by means of appropriate connector pipes and reducers,
- reduction of air temperature by minimum 5°,
- mass of all assemblies: up to 40 kg (can be carried by 2 people),
- cooling power: ca 3 kW,
- fan power: 0.5-1.1 kW (depending on the planned panel length) ,
- power supply from a 500-V electric network (or 400V, 230V – depending on the electric motor applied)

Task 1.2 Initial 3D modelling of equipment

General virtual model of the lightweight air conditioning system was developed (Fig.26.). The air conditioning system will supply cooled air (18-20 ^{o}C) transported at high velocity by a flexible plastic ventube of a diameter less than 200 mm. All the components of the unit will be easy for transportation because of their modular structure. The system will consist of a cooling unit with the compressor and condenser, ventube fan, cooler with vaporiser and flexible plastic ventube of the diameter 200 mm. However, we consider using the ventube of smaller diameter of about 120 mm due to small cross-section of the rescue tunnel. So far, the flow was calculated as well as the basic technical data of the unit have been determined and preliminary thermodynamics of the cooling process was calculated.

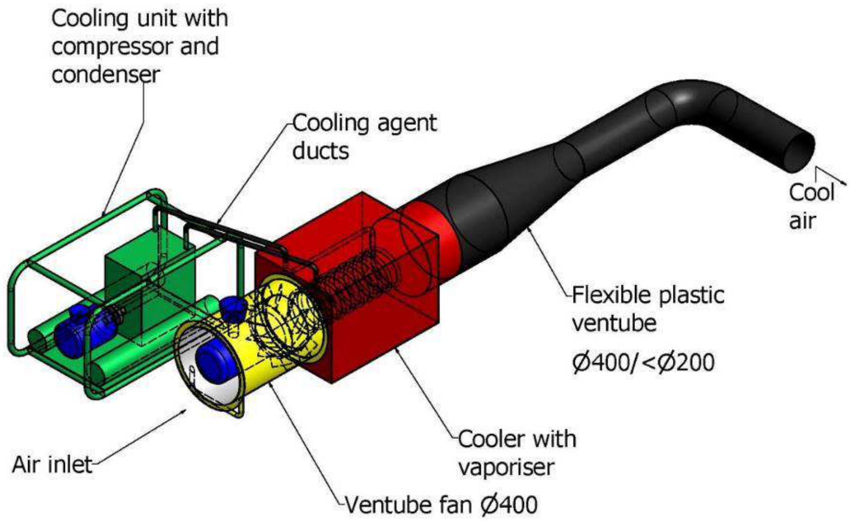


Fig. 26: 3D model of air conditioner

Task 2.2: Development of documentation of the rescue equipment

According to the developed documentation No. W66.090 the device consists of WR-320 rescue fan with CP-320 air cooler and cooling unit. It has a form of modules connected by flanges or by flexible ventube sections. Final analysis of geometry of fan flow system was made, the

curvature of blades of fan rotor was determined on the basis of this analysis and diameters of the system and rotor rim were selected. Fan diameter was reduced from 400 mm to 320 mm in relation to the initial assumptions, what improves its transportation and reduces its weight.
Thermal and thermodynamic calculations, which enable specifying the parameters of conversion of cooling agent in the system: cooling unit – air cooler, were made. Heat exchange in the cooler was calculated, what enabled to determine the size of pipes in the cooler. It was found that the surface of heat exchange provided by the pipes is enough for effective cooling the air stream and thus the idea of equipping the pipes with radiators was given up. Such solution will have a positive impact on hydraulics of the system, not generating excessive flow resistance.
It was also decided that the components of cooling unit will not be installed on the common carrying frame, what will enable their easier transportation, i.e. they will be transported separately, not as one big system of total weight of about 50 kg.
The air will be transported to the rescue working by flexible pipeline of diameter 120 mm, but behind the system, the ventube will change its diameter from 320 mm (diameter of each flow module) to 120 mm at the length of 600 mm.
The analyses decided about the design of the entire system. The components are shown on Fig.27

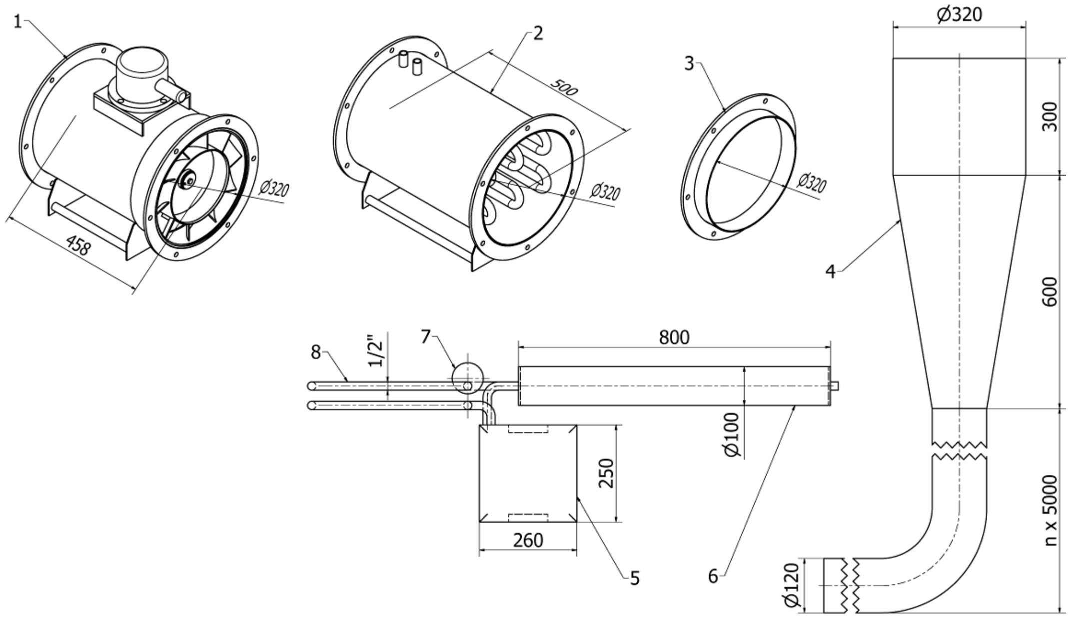


Fig. 27: Design of the main components of the air conditioner (1 –fan, 2 –cooler 3 –Flange of elastic hose, 4 –elastic hose , 5 –compressor , 6 –condenser, 7 –expansion valve 8 – elastic tubes)

Task 4.1 Manufacturing of prototype and experimental equipment

Elmech Kazeten company from Czeladź was responsible for manufacture of air conditioner. Sub-system of air conditioner fan was manufactured in 2014 (Fig.28.). T4.1 was finished in 2015 after completion of cooling section of air conditioner.

Fig. 28: Fan section (right) and complete of air conditioner manufactured by Elmech Kazeten (left)

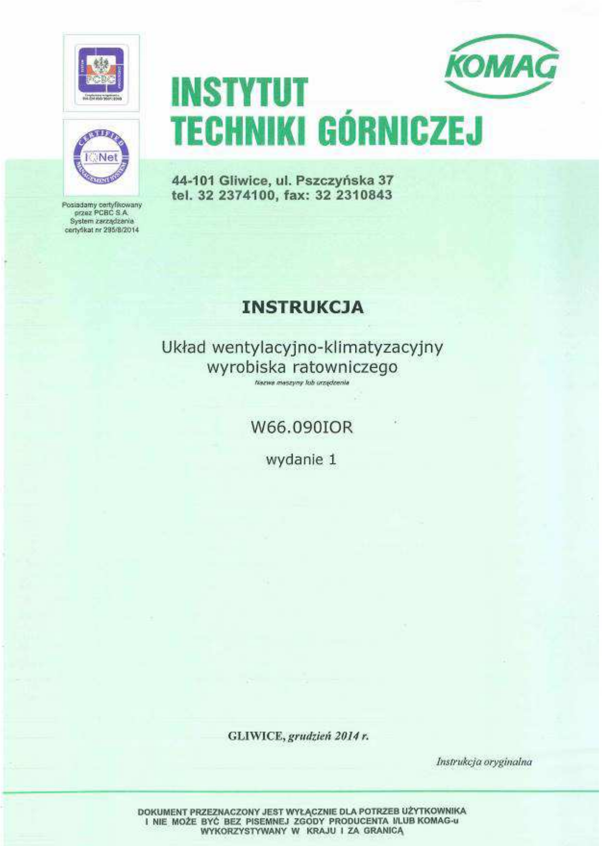
Task 5.2: Laboratory tests of prototypes of rescue devices and experimental devices

Representatives of CSRG were invited for the tests to be acquainted with the devices before sending them for tests at CSRG. The tests of air conditioner carried out in the KOMAG's laboratory is presented in Fig.29.

Fig.29: Testing the efficiency of air conditioner blower when air is supplied by ventube of diameter 120 mm

Task 6.2: ATEX, IECEx and mining company approvals of components (KOMAG, GAUK, DMT)

KOMAG has positively completed certification process for the air conditioner– Fig. 30.



KOMAG

INSTYTUT TECHNIKI GÓRNICZEJ

44-101 Gliwice, ul. Pszczyńska 37
tel. 32 2374100, fax: 32 2310843

Posiadamy certyfikowany przez PCBC S.A. System zarządzania certyfikat nr 295/8/2014

INSTRUKCJA

Układ wentylacyjno-klimatyzacyjny wyrobiska ratowniczego

Nazwa maszyny lub urządzenia

W66.090IOR

wydanie 1

GLIWICE, *grudzień 2014 r.*

Instrukcja oryginalna

DOKUMENT PRZEZNACZONY JEST WYŁĄCZNIE DLA POTRZEB UŻYTKOWNIKA I NIE MOŻE BYĆ BEZ PISEMNEJ ZGODY PRODUCENTA I/LUB KOMAG-u WYKORZYSTYWANY W KRAJU I ZA GRANICĄ

OBAC

Ośrodek Badań, Atestacji i Certyfikacji Sp. z o.o.
44-122 Gliwice, ul. Toruńska 27

(1) **CERTYFIKAT ZGODNOŚCI**

(2) Urządzenia, systemy ochronne i podzespoły przeznaczone do użytku w przestrzeniach zagrożonych wybuchem. Dyrektywa 94/9/WE. (Rozporządzenie MG z dnia 22.12.2005 r. Dz.U.Nr 263, Pozycja 2203).

(3) Certyfikat zgodności Nr: **OBAC 15 CZ/ATEX 0292X**

(4) Urządzenie lub system ochronny: **Układ wentylacyjno-klimatyzacyjny wyrobiska ratowniczego**

(5) Producent: **Elmech KAZETEN Sp. z o.o.**

(6) Adres: ul. Nowopogońska 98, 41-250 Czeladź

(7) Urządzenie niniejsze lub system ochronny oraz jakikolwiek jego zatwierdzony wariant jest specyfikowany w niniejszym certyfikacie i dokumentacji, której spis podano w pkt. 19.

(8) Ośrodek Badań Atestacji i Certyfikacji OBAC Sp. z o.o., zaświadcza, że w/w urządzenie lub system ochronny sprawdzono na zgodność z podstawowymi wymogami bezpieczeństwa i ochrony zdrowia dotyczącymi projektu, konstrukcji urządzenia i systemu ochronnego przeznaczonego do stosowania w warunkach zagrożonych wybuchem, które podano w załączniku nr II Dyrektywy Rady 94/9/WE z 23 marca 1994 r.
Wyniki badań podane są w poufnym raporcie nr: OBAC/15/ATEX/0292.

(9) Spełnienie podstawowych wymogów bezpieczeństwa zapewniono poprzez zgodność z:

PN-EN 13463-1:2010 (EN 13463-1:2009) **PN-EN 13463-5:2012** (EN 13463-5:2011) **PN-EN 1710+A1:2010** (EN 1710:2005+A1:2008)

(10) Jeżeli za numerem certyfikatu podano symbol "X" to w dalszym ciągu niniejszego certyfikatu podano specjalne warunki bezpiecznego stosowania wyrobu.

(11) Niniejszy certyfikat jest ważny w okresie od **25.06.2015** do **24.06.2018** i dotyczy wyłącznie egzemplarzy wyrobu (ów) posiadających identyczne właściwości (parametry) jak przedstawiony do oceny wzór (wzory) i odpowiadające wymogom określonym w pkt. 9 niniejszego certyfikatu.

(12) Oznakowanie niniejszego urządzenia lub systemu ochronnego musi zawierać poniższe symbole:

Ex **I M2 c**

Kierownik
Jednostki Certyfikującej

mgr Piotr Tarnawski

Gliwice, 25 czerwca 2015 r.

Druk OBAC/PO 1/F12 wyd. 7 Strona 1 z 3

Fig.30: Technical manual of air conditioner and the certificate for conformity of air conditioner which confirms that product is classified for group I category M2 according to 94/9/WE Directive (ATEX)

2.2.4. Rock fragmentation experimental device with low specific energy requirement

Technology for mining the solid rocks through destroying the rock mass cohesion, used among others in development of rescue tunnels, was considered by KOMAG. The simple, effective technology for mining the rocks of relatively low energy consumption, is the aim of suggested method. The work on that method and the dedicated UDWR-1 device was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Task 1.1 of WP1
Task 2.2 of WP2
Task 4.1 of WP4
Task 5.3 of WP5

Task 1.1 Determination of assumptions for prototype and experimental rescue equipment

Technology for mining the compact rocks through destroying the rock mass cohesion, used among others in development of rescue tunnels, was considered in task. The simple, effective technology for mining the rocks of uniaxial compression strength exceeding 100 MPa and of relatively low energy consumption, is the aim of suggested method. The technology for rock mass mining according to the suggested solution consists in drilling the boreholes in the face of working, to which expanding bolts are inserted (Fig.31). After wedging the expanding bolts in the boreholes, the bolts are pulled out, tearing out the fragments of rock mass.

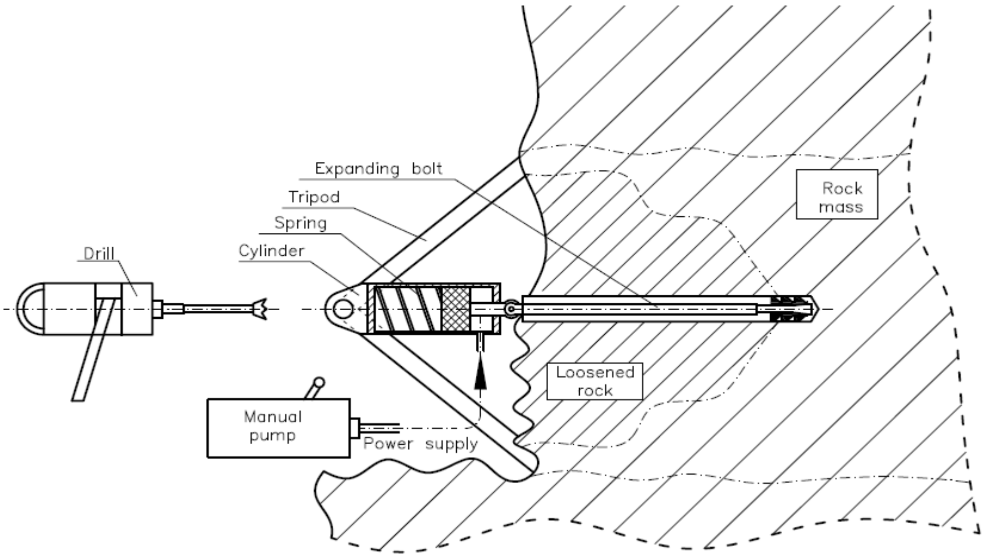


Fig. 31. Method for mining by tearing out rock blocks by expanding bolts

Expanding bolts with protruding end connected to the end of cylinder piston are inserted to the boreholes. The cylinder is installed on a tripod, which rests upon the rock around the borehole, outside the planned rock loosening zone. Feeding the oil to the under-piston compartment of the cylinder causes increase of stress to the rock and then tearing off rock fragments. The process repetition leads to working drivage. Replacing the tripod with a traverse, which can be connected to the cylinder by a string (e.g. chain of enough strength), is one of the versions of this technology.

Task 2.2: Development of documentation of the rescue equipment

Design work was continued on the basis of the results of tests that were carried out in Królowa Luiza mine in Zabrze. Proper depth of bolting was calculated. In the testing conditions, the best advantage was obtained at bolting depth of about 190 mm.

The bolts are designed to be manually inserted in the hole by tightening the nut. Tightening the nut causes expansion of jaws on the conical surface at the end of bolt core. It was suggested to use a hub equipped with longitudinal ball bearing during tightening the nut to decrease the friction resistance. Undertaken tests and strength calculations enabled to develop a new design of bolts showed in Fig.32.

W19.054 documentation of experimental device for cutting the rocks with use of low energy technology of was developed. The documentation was made in CAD programme.

a.)

b.)

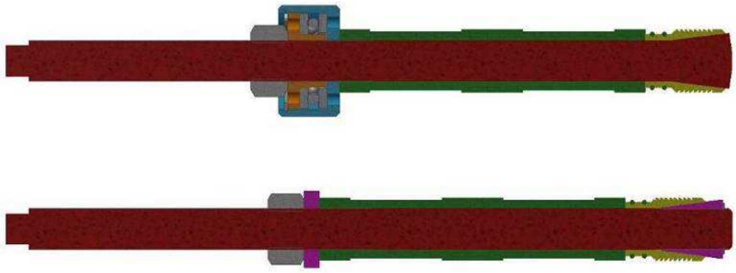


Fig.32. New design of bolt with expansion end
a) with bearing for compensating the resistance of tightened nut
b) without compensation of resistance of tightened nut

Task 4.1: Manufacturing of prototype and experimental equipment

The components of UDWR-1 experimental device for drivage of rocks were manufactured by Elektron company in Radzionków. The components of device are presented in Fig.33. There are the following components of UDWR-1 device: bearing support, manual hydraulic pump, safety tripod, bolts drilling machine, support for drilling machine, drills.

Fig.33. Components of UDWR-1 device (left) and the prototype of the bolt K-260 (right)

Task 5.3: Field tests of prototype rescue devices

The device was tested in the working of Królowa Luiza mine. TM-7 Protekt safety stand was used to suspend the UDWR-1 device and to determine its axis in relation to axis of bolt screwed in rock solid. Tearing of rock solid was started after suspension and fixation of bolt in RCH-606 single-acting cylinder of UDWR-1 device (Fig. 5.3-1).

The cylinder piston was moved and the bolt was torn with use of P-80 manual pump manufactured by ENERPAC.

The tests indicated that it is necessary to make changes in the prototype of UDWR-1 device. The structure of tripod support was strengthened, what enabled carrying out the next tests of usefulness of UDWR-1 device for tearing the rock solid. HDA-P bolts were used in the next tests. These bolts automatically extend the diameter of hole bottom during their fixation. It was necessary to drill the hole to fix the bolt. TE 70-ATC/AVR drilling machine manufactured by Hilti was used to drill the holes. The bolt was fixed after making the borehole and its insertion to the borehole. Fixation of bolts was possible due to the above mentioned drifter drill equipped with proper wrench (recommended by the manufacturer of bolts) fixed in the drill handle (Fig.34.).

Fig.34. Drilling the holes and fixing the HDA-P bolts

After fixing the bolt its end was fixed in UDWR-1 device and process of tearing the rock solid was started (Fig.35.).

Fig.35. Detaching the rock solid with use of HDA-P bolt

Tests of drivage of rock with use of HDA-P bolts showed that it is possible to tear the rock solid in a form of more or less regular cones. Sample rock cone that was torn is presented in Fig. 30 on the right side. Working available for testing, its infrastructure and work carried out by mine employees simultaneously to the tests enabled to carry out ten or so tests of rock tearing. During the tests the bolts were fixed at different depth and the measurements were recorded.

2.2.5. Rescue tunnelling demonstrator based on hydro cutting technology and the control panel

As the planned for manufacturing by ICOP the water-jet assisted tunnel-boring machine was not realized, the demonstrator to simulate the machine operation was developed and realized instead of. The control system, dedicated for previously planned machine was realized by AITEMIN and after their withdrawal finished by KOMAG.
The work on the demonstrator ad the control system was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Task 1.1, 1.5 of WP1
Task 2.1, 2.2, 2.4 of WP2
Task 4.1 of WP4
Task 5.3 of WP5
Task 6.2 of WP6

Task 1.1 Determination of assumptions for prototype and experimental rescue equipment:
CSRG, KOMAG and Geocontrol played the advisory and consultative role for AITEMIN and ICOP, which jointly develop the concept for a microtunelling device for cutting the rocks by hydro cutting method. The following assumptions were developed for such device:

1. Due to the difficulty of drilling a tunnel in rock falls area (collapsed areas), it's considered that the best option will be starting a new excavation in sound (healthy) rock next to the collapsed zone, i.e. at the distance of 2-5 m, that is, the device should be used only for tunnel drivage in a solid rock not in roof fall debris.
2. This implies the necessity of excavation curves (bends). Hence, this device should provide such operation.
3. The rock cutting device should cut even the hardest rocks found in mines
4. By the rescuers opinion the tunnel drivage rate should be at least 0.25 m/h
5. The cross-section should provide room for the movement of the rescuer with full equipment (breathing apparatus) and for transporting transport injured miners. Currently such rescue excavations are made in section 1.0m x 1.0m, but now the target is that the driven tunnel should have cross-section of maximum dimensions of 1.3m width x1.4m height
6. Cutter head should be of such size to enable its use in such space
7. Water and mined rock must be absolutely removed to allow further cutting
8. Necessity of using support for drilled excavation had to be considered.
9. Lightweight flight-bar (armoured) conveyor, which is under development in KOMAG can be used to remove debris, but water will not be removed by this conveyor.
10. Facility for transporting the material to end and from the end of working face (rescue excavation).
11. Facility for ventilating the excavation.
12. Facilities for removing the excavation device from the working face after drilling rescue excavation.

After considering the above, it was decided by the partners that the most appropriate solution will be implementing a micro-tunnelling device.

ICOP's activities focused on the analysis of technological opportunities related to micro-tunnelling. The following considerations were taken into account when considering applying the water assisted cutting technology from soft-medium rock to hard rock:

- Hard rock cutters use different head tools and configurations
- The use of water jets on industrial scale has not been found yet, only in papers and a few patent publications.
- The use of water jets is sometimes used for removing powder and dust while cutting
- Due to the cutting potential of water at high pressure, careful installation of water nozzles is necessary
- No parts of the machine have to be in direct contact with the water jets
- Access to the cutting head has to be guaranteed in order to supply water

Task 1.5 Preliminary work bench for hydro-cutting technologies

AITEMIN and ICOP activities were focussed on the analysis of technological opportunities related to micro-tunnelling via hydro-jetting.
The cutting system will be composed of hydro cutters, running at high pressure and placed at the front of the machine. Because the measurements to assess the performances of the new system in real working conditions could be difficult and expensive, a preliminary work bench will be developed to analyze the behaviour of the hydro-cutting technologies according to the rock and coal strength in mine rescue conditions. An approach based on Design of Experiment (DoE) for performing the tests will be applied. Existing workbenches were reviewed.

ICOP analysis gave the following information:

- there is a high demand for non-destructive techniques such as mechanized construction of tunnels;
- present TBM is too expensive and have low advance rates. Innovation in this area is however of paramount importance and one of the most promising new technologies is the water jet cutting;
- studies on the use of water-jet for tunneling purpose, i.e. rock excavation, indicates that high power waterjet, instead of high pressure waterjet is more adequate for excavating rocks;
- tests have shown that the mechanism of crack growth can be more easily reached by increasing the fluid flow at a given pressure rather than by increasing the pressure at a constant flow. This was illustrated by data from an experiment in which both flow rate and pressure were varied in cutting coal. As the pressure increased the specific energy of cutting only decreased slightly. In contrast, where the power was increased by enlarging the jet, the volume removed increased more than equivalently, with a larger drop in specific energy;
- other experimental results revealed that the conventional high pressure waterjet (with pressures up to 420 MPa and a working rate up to 30 kW) for cutting purposes have a very limited cutting depth (about 15 cm); hence it cannot be used for tunneling purposes, in which a cutting depth of few meters is desired. Therefore, the waterjet with somewhat lower pressure (about 150 MPa), but much larger working power (more than 300 kW) used for hydro-demolition, has to be considered for tunneling purposes;
- in particular the combined usage of high power waterjet and abrasive waterjet shows versatile applicability in rock excavation, which can be adopted in tunneling engineering and slope engineering;

Finally, it was decided that the test bench would be based on the lathe concept. As its main objective is testing the efficiency of the hydro-cutting technology on different types of rocks, the nozzles do not need to be rotating. Instead, a rotating base holding a rock block will simulate the motion of the cutters relative to the rock. The waterjet nozzles will be fixed on the side of the cutters, simplifying the construction and operation of the test bench. A rotating high-pressure water distribution system will be implemented later on into the demonstrator device. The executive design of the final test bench concept has been completed.

Task 2.1: Design studies of equipment prototypes

Accurate description of the work phases during tunnelling operations was provided by ICOP, in particular concerning the approach to tunnelling operations performed via µTBM.
Based on initial output from the consortium, a novel rescue approach scheme proposed by ICOP has been adopted after approval by all partners. The resulting preliminary concept of the waterjet-assisted µTBM concept is shown in Fig 36.

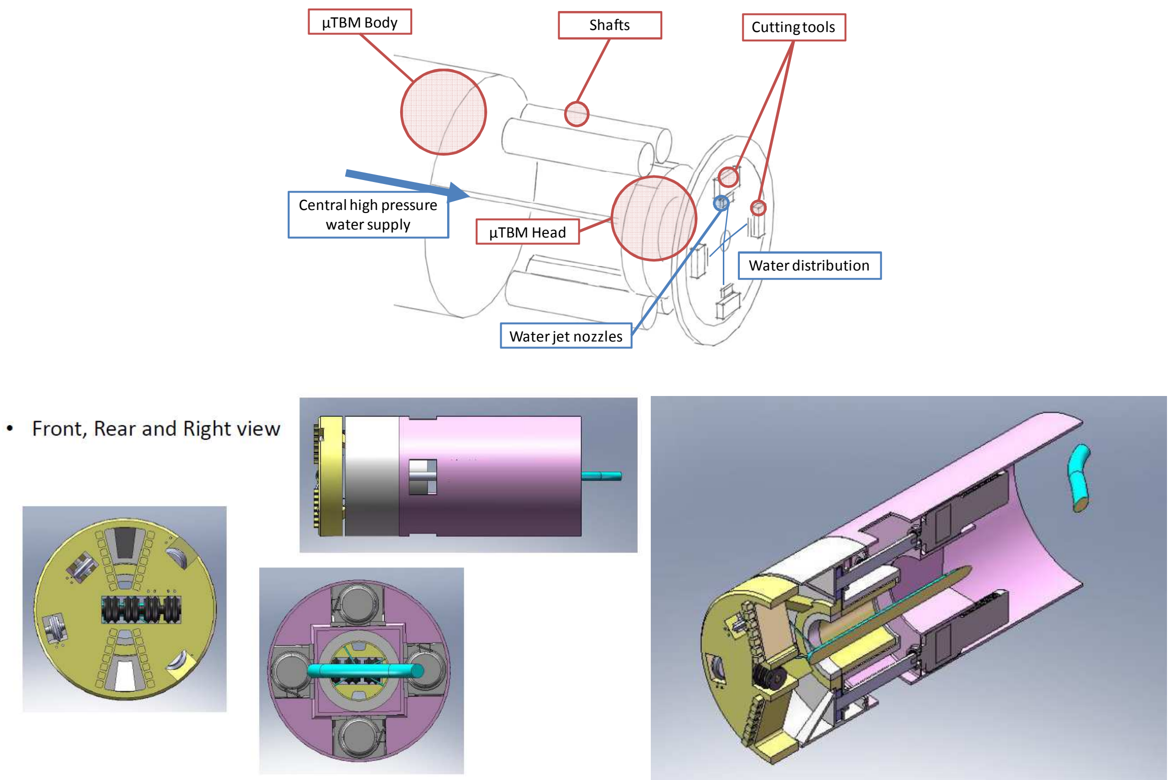


Fig.36: Preliminary concept and 3D model of the waterjet-assisted micro-tunnelling device

The main component of the control system of the rescue tunnelling machine was selected: the ATEX-certified, M1 category, single-board MP-40 computer that will be used to monitor and control the state of the different elements of the machine.

Task 2.2: Development of documentation of the rescue equipment

ICOP prepared technical documentation of the hydro cutting demonstrator – Fig.37.

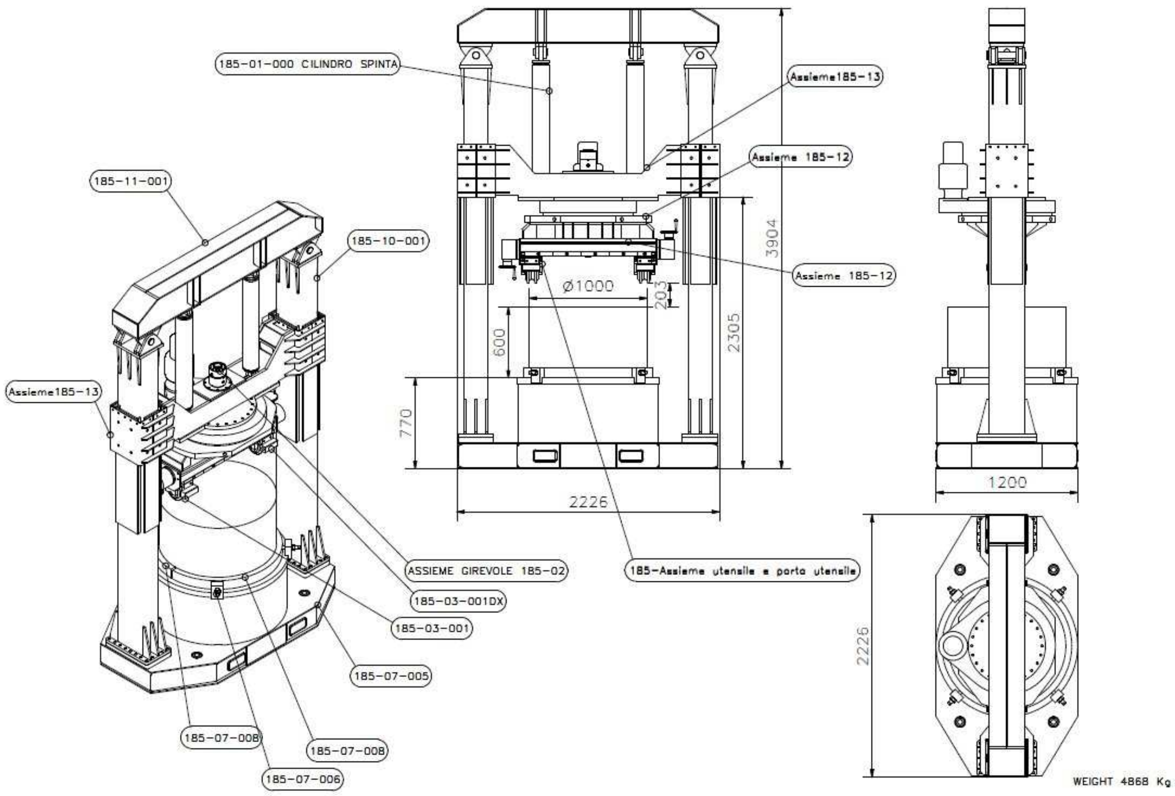


Fig. 37: Technical drawing of the hydro-cutting demonstrator - main drawing

Task 2.4: Results and assessment of the workbench for hydro-cutting prototype

The numerical analyses were performed combining the SPH and FEA. This allows to study the interaction of high-velocity water jet impacting the rock. The water jet was modelled by SPH particles and the rock was modelled by finite elements. The hybrid-code of SPH and FEA was conducted to simulate the penetration process, and the computational result gave the relationship between the water jet velocity, exposure time and the depth of cut. The example of the test carried out using the material of Young's modulus E = 70 GPa with a water jet velocity of 700 m/s (adequate to the pressure of 245 MPa) is shown in the Fig. 38

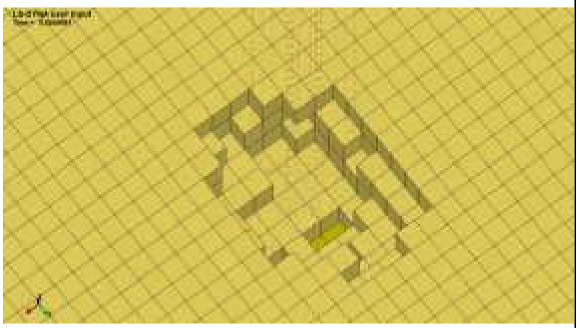
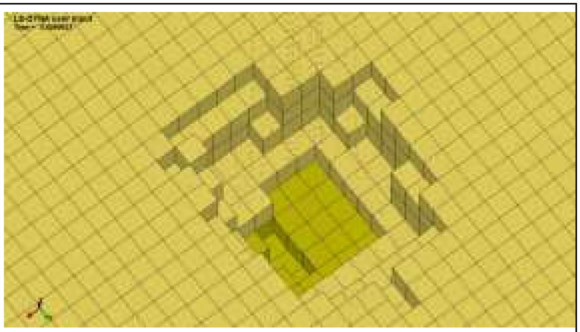
	
t = 50 µs; max depth = 0.6 mm	t = 100 µs, max depth = 1 mm

Fig. 38: Example of the results of the numerical anallyses of water jet impacting the rock

The objective of these analyses was to set up a numerical model able to understand the erosion mechanism of the water jet and the influence of the water jet velocity (or pressure) on the different types of rock, characterised by an e elastic material model with implemented a strain-failure criterion

Task 4.1: Manufacturing of prototype and experimental equipment

The proposed structure of the control system of the cutting machine prepared by AITEMIN is shown in Fig.39. Hardware used was certified: FAR-V20 1A, MP40-RTU Ex and UCR-AV. Optionally, DIGICOM can be connected for fixed voice transmission.

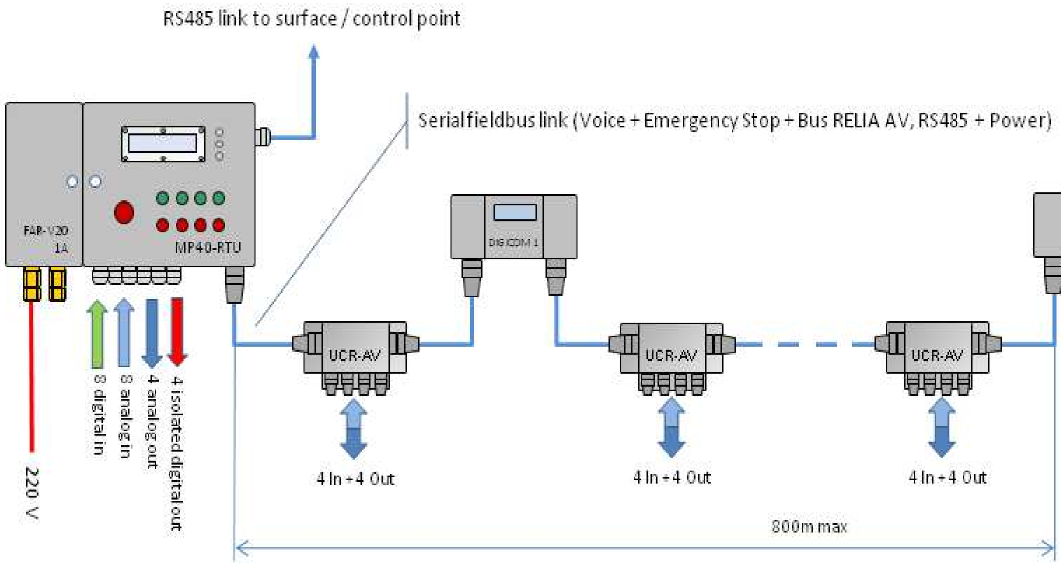


Fig.39: Structure of a control system for underground cutting machine

Figure 40shows the proposed configuration of the new Control System for the µTBM, which is split between the machine room and the control desk located at the control cabin.

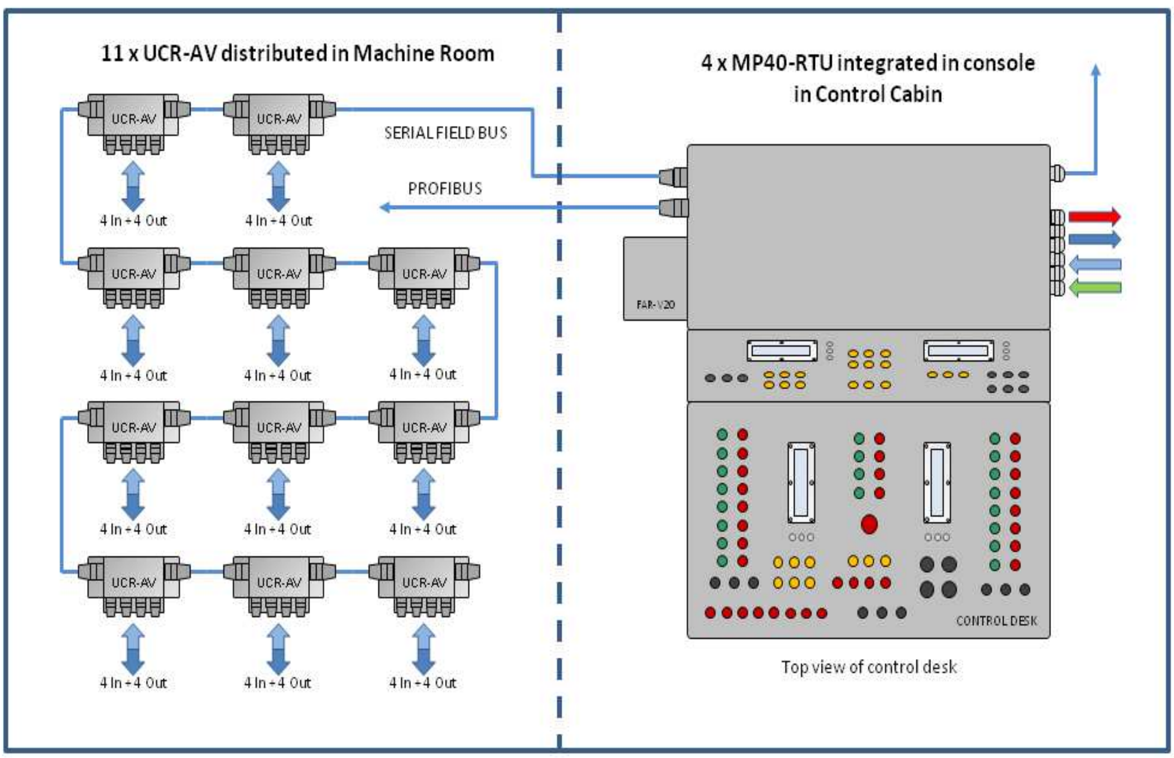


Fig.40: Proposed configuration of the new control system, split between the two rooms of the Main Distribution Container: the machine room and the control cabin.

In a result of AITEMIN's withdrawal from the project,KOMAG took over their work. Development of control panel was continued while ICOP made the complete demonstrator for testing – showed on Fig. 41.

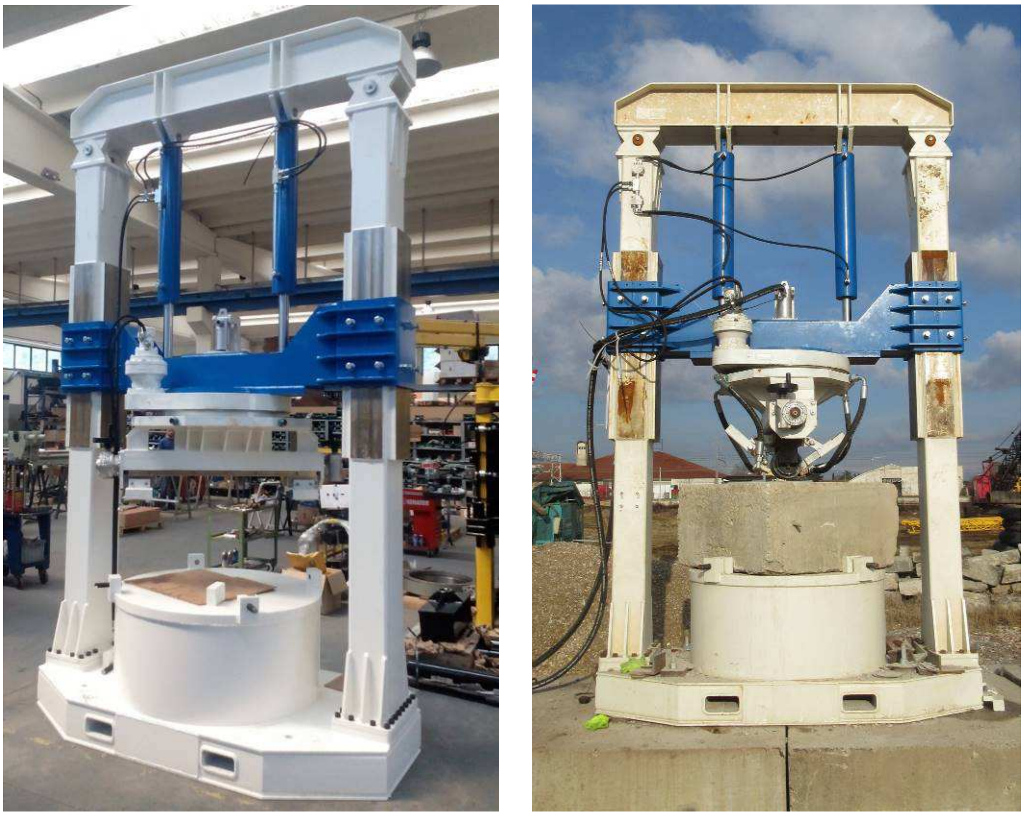


Fig. 41: Demonstrator made by ICOP

The water jet assisted cutting head demonstrator is characterized by:

- a fixed table on which the rock block is positioned;
- a rotating system able to recreate the µ-TBM (micro Tunnel Boring Machine) cutter head with fixed two double-cutters and the water jet nozzles;
- an hydraulic circuit to supply water to the nozzles installed on the rotating system;
- hydraulic pistons used to push the rotating system of the cutters against the rock.

KOMAG designed and manufactured system for control of rock machine boring. The system was tested on a stand simulating the drivage process. System for simulation of tunnel boring machine control is presented in Fig.42. The system consists of the stand of operator and simulator of the boring machine.

Fig. 42: System for simulation of boring machine control

The following modules are installed on a desk of the stand of operator of tunnel boring machine (Fig.43):

- PO-1 – Operator's Panel. It is used for presentation of data of the control system. PO-1 panel is equipped with fibre optic interface, which task is to communicate with computers installed beyond area threatened by methane and/or coal dust explosion hazard. During the tests, the fibre optic interface will be used for communication with the virtual model of rock boring machine.
- MIS-1 – Module of Intelligent Controller. It is used for presentation of data of the control system
- KS-1/20 – Control Cassette. KS-1/20 control cassette includes control buttons, signalling lights and setters indispensable for manual control of machine.

Components of the simulator of rock boring machine are shown in Fig. 43.

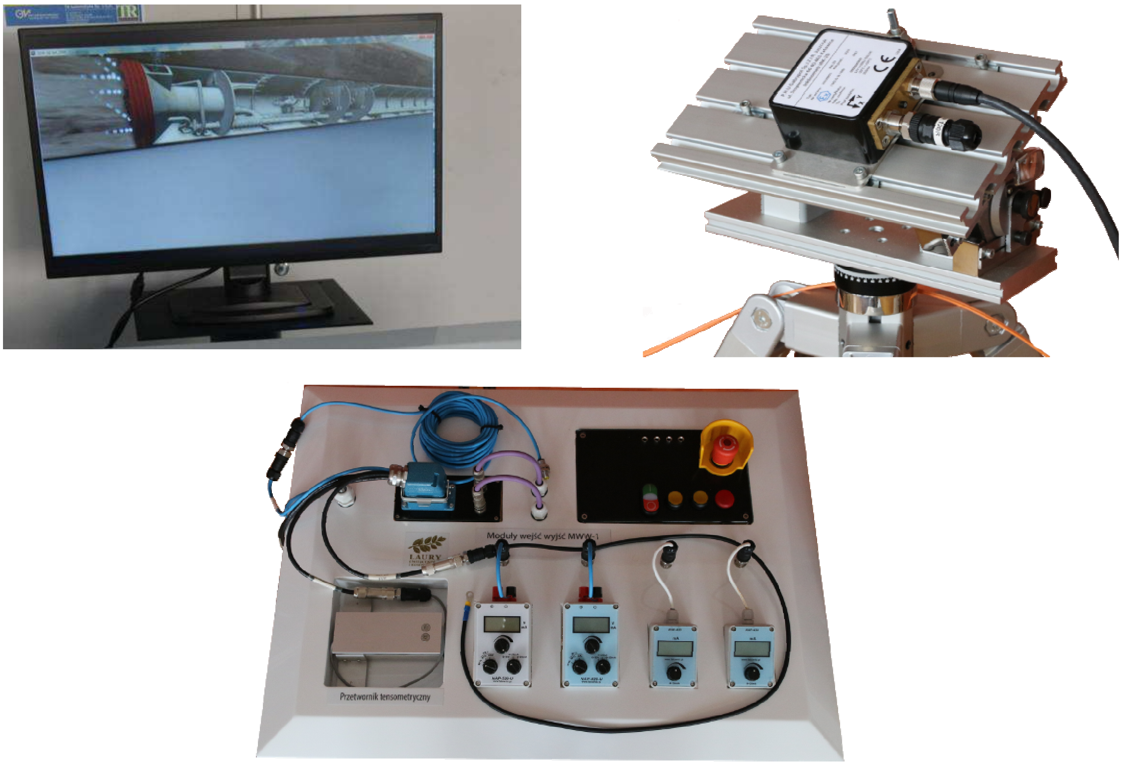


Fig. 43: Components of the simulator system of rock boring machine

The simulator consists of the following components:

- Visualization programme simulating the rock-boring machine (PC with monitor).
- Module of INK-2D inclinometer installed on a adjustable table.
- Desk with setters simulating the sensors installed in a head of cutting machine. The setters are connected to the MWW-1 module (Inputs-Outputs Module), which enables to send analogue data of setters through CAN bus to PO-1 and MIS-1 modules. The following setters are installed on the desk:
  - 4-20 mA (simulating the pressure sensors in a hydraulic system, flow sensors and sensors of position with output current 4-20 mA).
  - 0-10V (simulating the pressure sensors in a hydraulic system, flow sensors and sensors of position wit output voltage 0-10V).
  - Strain gauge converter (simulating the sensors of strain of the components of rock boring machine).
  - PT100 thermometric resistor (simulating the temperature sensors).

The modules (MWW-1, MIS-1 and PO-1) are connected with each other through CAN bus. Presented modules installed on the stands were also connected to numerical model of the machine by fibre optic, which connected PO-1 panel with a computer with a programme for simulation of machine operation. Data were transferred between the programme and panel with use of standard TCP/IP protocol.
PO-1 operator's panel, selected for using in the system for control of rock boring machine, is the intrinsically safe device dedicated for machines operating in areas threatened by explosion of methane and/or coal dust. The device equipped with 7'' screen enables displaying information about the selected parameters and visualization of the controlled processes PO-1 Panel is a device for use in industrial automatics system adapted for operation in a potentially explosive atmosphere of methane and/or coal dust. Operators panel consists of LCD colour displayer of resolution

800x480, two-position inputs and outputs, analogue inputs as well as CAN, ETHERNET digital interfaces and USB. Panel is adapted for creation of redundant control system with use of CAN bus. It is realized by two independent, galvanically isolated CAN interfaces. PO-1 panels (two items) together with KS-1 assembly (Fig.44.) play a role of master controller in the machine's control system and they are installed on the operator's stand.

Fig.44: PO-1 operator's panel (left) and KS-1 controlling assembly (right)

KS-1 assembly is equipped with buttons, signalling lamps and emergency switch, which enable controlling the machine.

Graphics indispensable for the operator's panel was made using the software for creation and processing the raster graphics – GIMP 2.8. Each of graphics elements were designed for screen resolution 800 x 480 pixels. Internal format of recording the graphical files of GIMP – XCF programme was used to make edition of developed projects possible. Format XCF does not use compression and keeps all markings, layers, channels and paths, which were used.

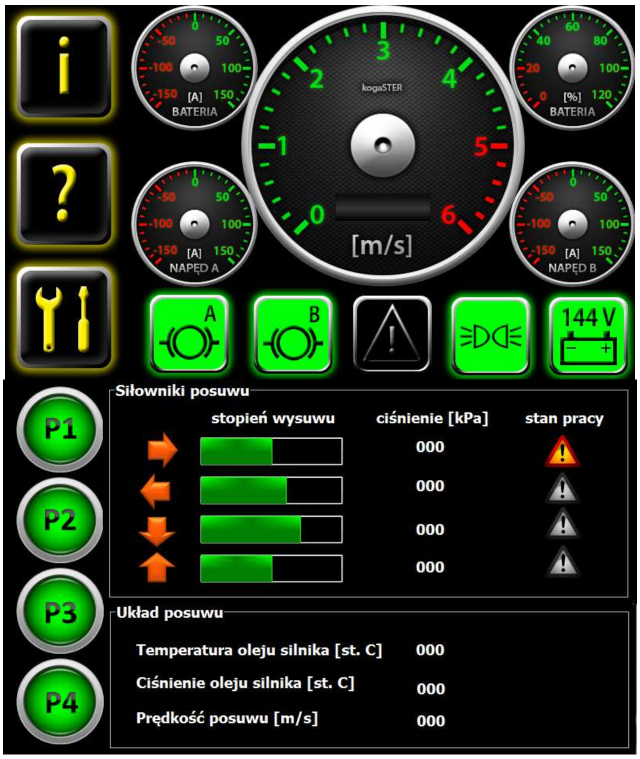


Fig.45: Sample of graphics designed for PO-1 operator's panel

The following types of elements were designed for graphical presentation in PO-1 panel the operation of controlling assemblies (Fig.45):

- commands buttons,
- two-position buttons on/off,
- temperature indicators,
- circular indicators,
- progress bars,
- signalling elements.

The designed graphical elements were used in programming the PO-1 panel. Detailed selection of each element was realized at the stage of implementation of programme's code.

Communication with the cutter head's control system wasrealized though an optical fibre cable. Communication uses the standard ETHERNET protocols.

PO-1/PN memory stick is connected through USB interface and is used to record data processed by the control system.

Inputs-Outputs Module:
The module is equipped with analogue outputs 0÷10V, 0÷20 mA or 4÷20 mA. Converters of nonelectrical physical quantities such as extensometric bridges, thermometer resistors, converters of extension of hydraulic cylinders, used in the control systems are connected to module's inputs. The module (Fig.46.) is of small size and has a possibility of individual adaptation of output connectors. The module and connected converters are supplied from one intrinsically safe feeder. The module's feeder can also be used to supply converters made in intrinsically safe version. Converters supplied with 12V are connected to the module. Moreover, strain gauges and thermometric resistors PTC and NTC are connected to the module. Unpolarized contacts or NAMUR induction proximity detectors are connected to two-position inputs of the module. Unpolarized contacts of the module were used to control the hydraulic distributors and motor switches. The software of the module is in accordance with CiA DS301 and DS401 Standards for CANopen protocol.

a)

b)

c)

Fig. 46: Module of analogue and digital inputs and outputs manufactured in two versions: a)MWW-1/1, b) MWW-1/2 and c) module of MIS-1 intelligent controller

Intelligent controller Module MIS-1
Showed on Fig.46 c plays a role of controller and man-machine interface. It is compatible with PO-1 operator's panel. The module is equipped with two independent, intrinsically safe CAN interfaces, four two-position inputs for connection of unpolarized contacts or NAMUR induction sensors and four two-position outputs as unpolarized contacts in a semiconductor version. Moreover, the module has one contact of the relay for control of motor switch. OLED monochromatic display of 256x64 resolution and buttons for navigationin the menu enable local control of operation mode of the control system.

Task 5.3: Field tests of prototype rescue devices

Within the task IOP realized series of tests on the demonstrator. Efficiency of cutting Two blocks, granite and concrete, were tested with using water jets assisted streams and without water jets.

Fig.47 Test of cutting efficiency (left) visit in ICOP during the tests (right)

The tests showed that the use of high pressure water jets increases the cutting depth (Fig 48), both in concrete and granite:

- Granite: the cut rock volume with water jets (using 400 bar) is about four times higher than that obtained without water jets, considering the same pushing force (8T);
- Concrete: the cut rock volume with water jets (using 400 bar) is about three times higher than that obtained without water jets, considering the same pushing force (8T).

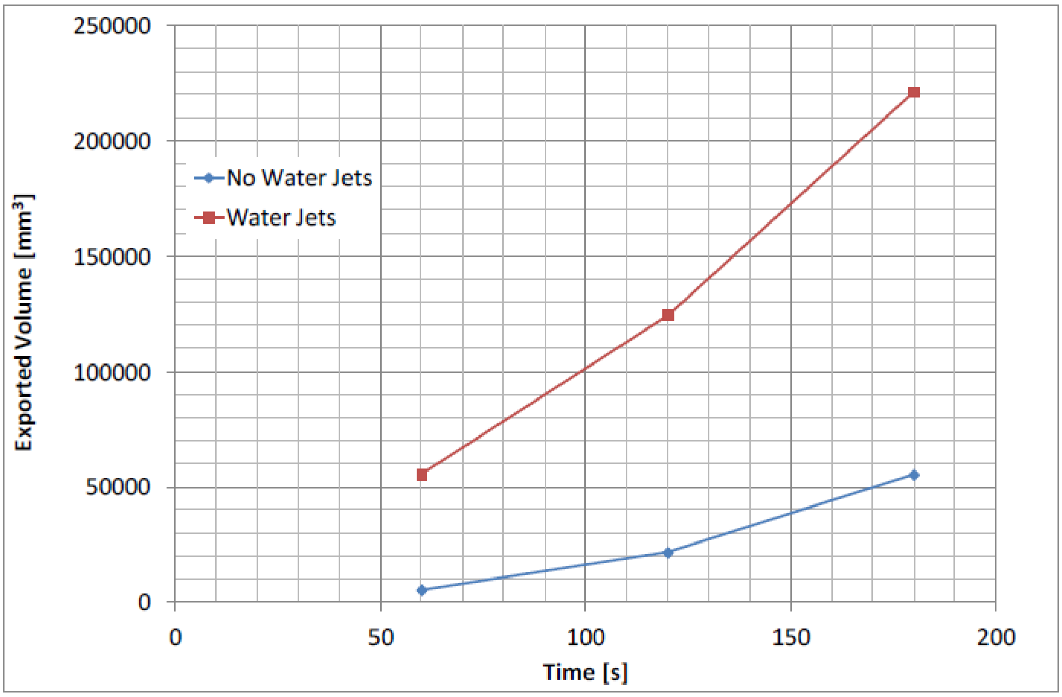
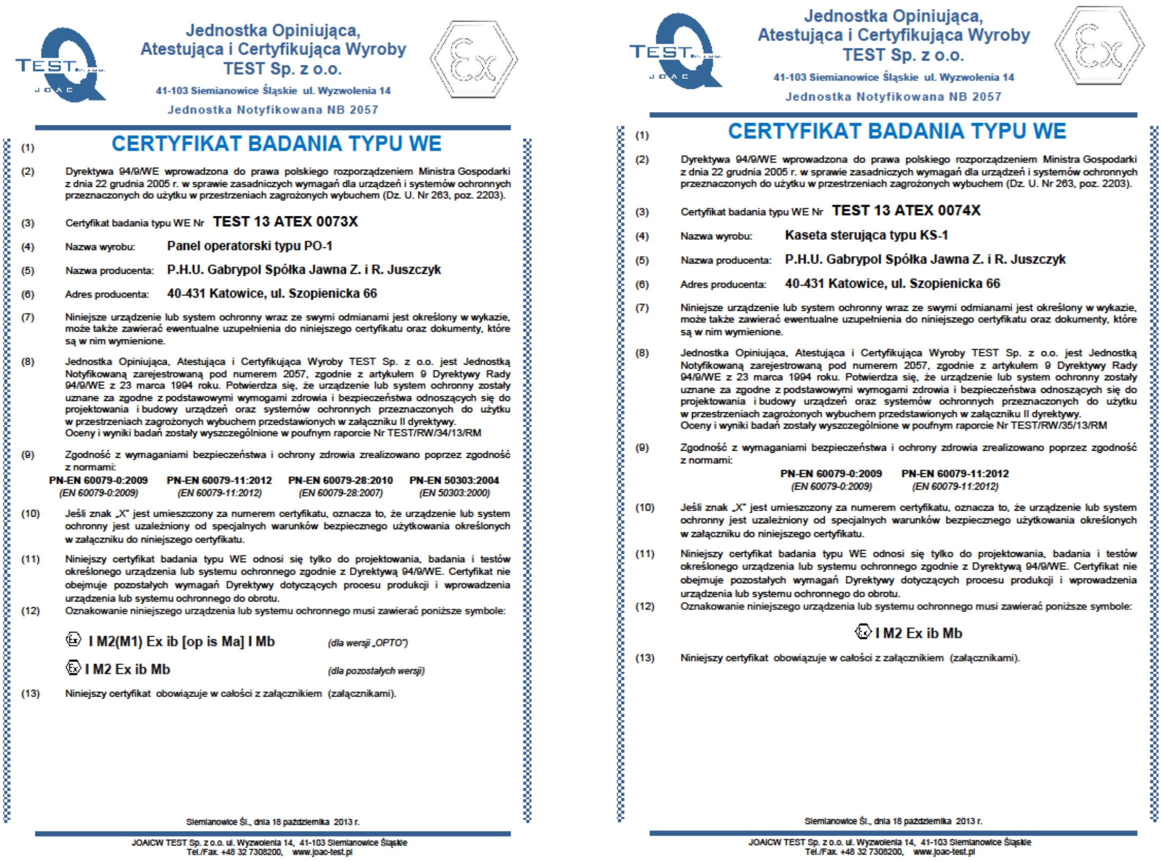


Fig.48 Cutting efficiency as destroyed rock volume as a function of time, with/without water-jets on the granite block

Task 6.2: ATEX, IECEx and mining company approvals of components (KOMAG, GAUK, DMT)

External companies manufactured the modules. After manufacture, the modules were certified for conformity with the standards harmonized with ATEX Directive. KOMAG has positively completed certification process for components of the control system – Fig. 49.



Jednostka Opiniująca, Atestująca i Certyfikująca Wyroby TEST Sp. z o.o.
41-103 Siemianowice Śląskie ul. Wyzwolenia 14
Jednostka Notyfikowana NB 2057

(1) **CERTYFIKAT BADANIA TYPU WE**

(2) Dyrektywa 94/9/WE wprowadzona do prawa polskiego rozporządzeniem Ministra Gospodarki z dnia 22 grudnia 2005 r. w sprawie zasadniczych wymagań dla urządzeń i systemów ochronnych przeznaczonych do użytku w przestrzeniach zagrożonych wybuchem (Dz. U. Nr 263, poz. 2203).

(3) Certyfikat badania typu WE Nr **TEST 13 ATEX 0073X**

(4) Nazwa wyrobu: **Panel operatorski typu PO-1**

(5) Nazwa producenta: **P.H.U. Gabrypol Spółka Jawna Z. i R. Juszczyk**

(6) Adres producenta: **40-431 Katowice, ul. Szopienicka 66**

(7) Niniejsze urządzenie lub system ochronny wraz ze swymi odmianami jest określony w wykazie, może także zawierać ewentualne uzupełnienia do niniejszego certyfikatu oraz dokumenty, które są w nim wymienione.

(8) Jednostka Opiniująca, Atestująca i Certyfikująca Wyroby TEST Sp. z o.o. jest Jednostką Notyfikowaną zarejestrowaną pod numerem 2057, zgodnie z artykułem 9 Dyrektywy Rady 94/9/WE z 23 marca 1994 roku. Potwierdza się, że urządzenie lub system ochronny zostały uznane za zgodne z podstawowymi wymogami zdrowia i bezpieczeństwa odnoszących się do projektowania i budowy urządzeń oraz systemów ochronnych przeznaczonych do użytku w przestrzeniach zagrożonych wybuchem przedstawionych w załączniku II dyrektywy.
Oceny i wyniki badań zostały wyszczególnione w poufnym raporcie Nr TEST/RW/34/13/RM

(9) Zgodność z wymaganiami bezpieczeństwa i ochrony zdrowia zrealizowano poprzez zgodność z normami:
PN-EN 60079-0:2009 *(EN 60079-0:2009)* **PN-EN 60079-11:2012** *(EN 60079-11:2012)* **PN-EN 60079-28:2010** *(EN 60079-28:2007)* **PN-EN 50303:2004** *(EN 50303:2000)*

(10) Jeśli znak „X" jest umieszczony za numerem certyfikatu, oznacza to, że urządzenie lub system ochronny jest uzależniony od specjalnych warunków bezpiecznego użytkowania określonych w załączniku do niniejszego certyfikatu.

(11) Niniejszy certyfikat badania typu WE odnosi się tylko do projektowania, badania i testów określonego urządzenia lub systemu ochronnego zgodnie z Dyrektywą 94/9/WE. Certyfikat nie obejmuje pozostałych wymagań Dyrektywy dotyczących procesu produkcji i wprowadzenia urządzenia lub systemu ochronnego do obrotu.

(12) Oznakowanie niniejszego urządzenia lub systemu ochronnego musi zawierać poniższe symbole:

I M2(M1) Ex ib [op is Ma] I Mb *(dla wersji „OPTO")*

I M2 Ex ib Mb *(dla pozostałych wersji)*

(13) Niniejszy certyfikat obowiązuje w całości z załącznikiem (załącznikami).

Siemianowice Śl., dnia 18 października 2013 r.

JOAICW TEST Sp. z o.o. ul. Wyzwolenia 14, 41-103 Siemianowice Śląskie
Tel./Fax. +48 32 7308200, www.joac-test.pl

Jednostka Opiniująca, Atestująca i Certyfikująca Wyroby TEST Sp. z o.o.
41-103 Siemianowice Śląskie ul. Wyzwolenia 14
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(3) Certyfikat badania typu WE Nr **TEST 13 ATEX 0074X**

(4) Nazwa wyrobu: **Kaseta sterująca typu KS-1**

(5) Nazwa producenta: **P.H.U. Gabrypol Spółka Jawna Z. i R. Juszczyk**

(6) Adres producenta: **40-431 Katowice, ul. Szopienicka 66**

(7) Niniejsze urządzenie lub system ochronny wraz ze swymi odmianami jest określony w wykazie, może także zawierać ewentualne uzupełnienia do niniejszego certyfikatu oraz dokumenty, które są w nim wymienione.

(8) Jednostka Opiniująca, Atestująca i Certyfikująca Wyroby TEST Sp. z o.o. jest Jednostką Notyfikowaną zarejestrowaną pod numerem 2057, zgodnie z artykułem 9 Dyrektywy Rady 94/9/WE z 23 marca 1994 roku. Potwierdza się, że urządzenie lub system ochronny zostały uznane za zgodne z podstawowymi wymogami zdrowia i bezpieczeństwa odnoszących się do projektowania i budowy urządzeń oraz systemów ochronnych przeznaczonych do użytku w przestrzeniach zagrożonych wybuchem przedstawionych w załączniku II dyrektywy.
Oceny i wyniki badań zostały wyszczególnione w poufnym raporcie Nr TEST/RW/35/13/RM

(9) Zgodność z wymaganiami bezpieczeństwa i ochrony zdrowia zrealizowano poprzez zgodność z normami:
PN-EN 60079-0:2009 *(EN 60079-0:2009)* **PN-EN 60079-11:2012** *(EN 60079-11:2012)*

(10) Jeśli znak „X" jest umieszczony za numerem certyfikatu, oznacza to, że urządzenie lub system ochronny jest uzależniony od specjalnych warunków bezpiecznego użytkowania określonych w załączniku do niniejszego certyfikatu.

(11) Niniejszy certyfikat badania typu WE odnosi się tylko do projektowania, badania i testów określonego urządzenia lub systemu ochronnego zgodnie z Dyrektywą 94/9/WE. Certyfikat nie obejmuje pozostałych wymagań Dyrektywy dotyczących procesu produkcji i wprowadzenia urządzenia lub systemu ochronnego do obrotu.

(12) Oznakowanie niniejszego urządzenia lub systemu ochronnego musi zawierać poniższe symbole:

I M2 Ex ib Mb

(13) Niniejszy certyfikat obowiązuje w całości z załącznikiem (załącznikami).

Siemianowice Śl., dnia 18 października 2013 r.

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Fig. 49: Certificates of the control system: PO-1 operator's panel and KS-1 controlling assembly

2.2.6. MK3 m-Comm communication system

GAUK based its data transfer system on its existing m-Comm technology. The objective was to modify the Mk 2 wireless m-Comm developed under RAINOW (RFCS, 2008), to be able to transfer the gathered information from the forward rescue team to the fresh air base for immediate analysis.
The work on the demonstrator ad the control system was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Task 1.1, 1.4 of WP1
Task 3.1, 3.2 of WP3
Task 4.2 of WP4
Task 5.1, 5.4 of WP5
Task 6.2 of WP6

Task 1.3: Specifications for Data Transfer System Protocols and Interfaces

The task established an outline of a data protocol that would be capable of transmitting gathered information from external transponders and portable equipment/meters.

Fig.50**.** shows a graphical representation of this system. The wireless section is not significantly speed restricted whereas the m-Comm up-link is a half-duplex audio system requiring data to be interleaved with the higher priority two-way speech traffic. Therefore the data in the 'hub', i.e., between the wireless link and the m-Comm handheld, (or reel hub), unit was buffered and transmitted in-between voice occupied periods. The data traffic must also be sent in a way that would not interfere with or delay normal voice communications. The embedded software algorithm to achieve this complex priority selection and implementation required careful consideration and proving.

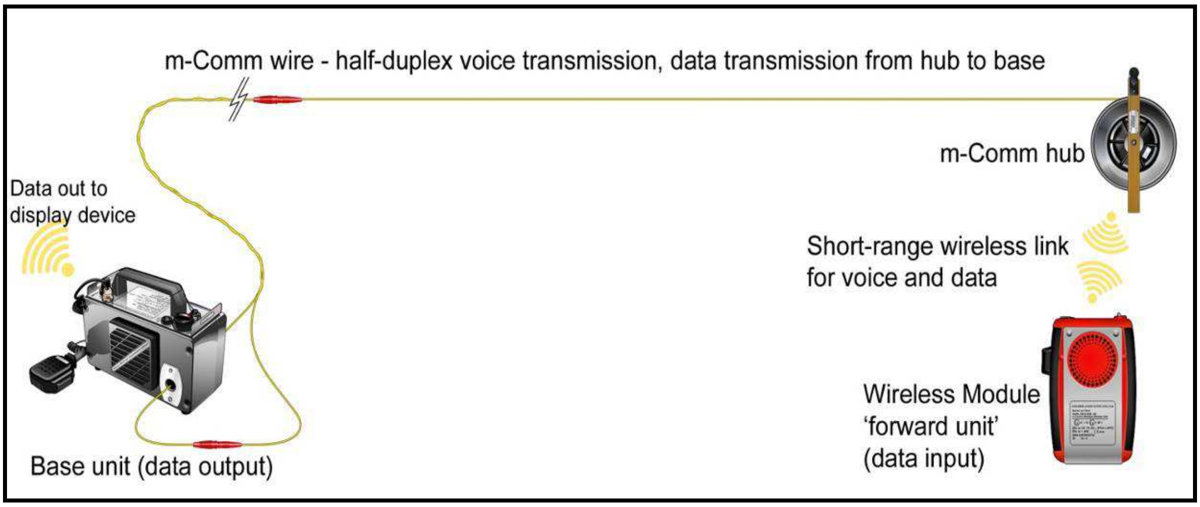


Fig.50: Graphical representation of the MK 2 m-Comm system with respect to voice and data transmission

The surface (or fresh air) base unit required only minor changes to the embedded software control, to avoid transmission collisions, etc. However, the base unit did require a separate and purpose designed module to extract, (and decode), the data transmission and an output interface. It was envisaged that this output interface would take the form of a wireless link or USB connection. The design of the m-Comm uplink was undertaken as a complete sub- system which included the extra data-out module in the base unit.

Transmission Rate:
Transmission rate was designed to be in 1200 bauds FSK, (assuming 1 millisecond per bit) with the data transmitted in packages of 300 millisecond (ms) bursts. This is based on 300 ms being the maximum delay tolerable in normal conversation, i.e., as experienced in satellite telephone or video links. The expected number of sensor readings per data transmission burst is 5 to 10 (from the optional sensor listed in D1.3). This gives a live graph updated, on average, once every 20 seconds. High speech occupancy naturally reduces the update rate. The specified graph update rate is based on being able to transmit between 0 and 100 data bursts per minute.

Protocol:
The message format takes the conventional 8 bits of data, stop, start checksum and some form of identity. Transmitted data coding was in hexadecimal (HEX) form.

With these initial specifications, the design of embedded software programs was outlined for each section of the system.
In the wireless module - firmware was required for the routing of data from the wireless module PIC processor, (received via the input interface specified below), to the Bluetooth module in a suitably packaged form, e.g., each sensor data and ID in HEX form.
In the Hub unit (handheld or reel hub)- firmware was designed to gather the data stream from the Bluetooth chip in the wireless interface module in the handheld or reel hub and store/buffer. At this stage, buffer overflow logic was designed on the basis of discarding old data for new data.
Commanding forward data transmission required similar instructions as set to initiate an audio broadcast, 'press to talk', but with an alternative CTCSS tone. In addition, the PIC processor generate the keyed FSK tones. Since this transmission is asynchronous additional 'system locking' bits were generated and placed at the beginning of the data stream.
The algorithm for commanding forward data transmission is critical for ensuring reliable co-existence of the voice and data traffic. Therefore, in its simplest form, it was envisaged that audio traffic (via PTT and un-mute) be monitored and if clear a data burst can be sent. The interruption delay from the audio function in the middle of a data burst was 300 ms or less at the design stage. The results showed that the data burst turn out to be less than the targeted 300 ms. It transpired that there were other small delay mechanisms, like the turn on times of data decoding circuits (30 ms) etc., but fortunately the actual data burst and circuit response delays less than 240 ms.
In the base unit - the base unit data-out and interface module functioned independently of the audio section and did not require significant modification to the existing PIC processor's embedded software. The data-out module was under its own PIC processor control, mainly for its output interface functions.

Input Interface:
The sensor interface circuits are located in the m-Comm wireless module and wired to available sensors. The digitized data was then buffered and channelled via a Bluetooth link to the hub. The initial sensor input specification were as follows:

- 3 analogue and
- 3 digital with
- Plus a 3V power out.

Each analogue input was 3 volt (V) sensing with an input impedance of 2.2k ohms or more. Digital inputs were again based on 3 V with zero between 0 and 0.9 V and one between 2.1 and 3 V. An external 3 V source was available for powering sensors via a 14 ohm resistor. The proposed ATEX certification is expected to require the following interface limitations:

- V_o = 4.5 V
- I_o = 9mA
- P_o = 10.2mW
- L_o = 438mH
- C_o = 100uF

Task 1.3 established an outline of a data protocol that will be capable for transmitting the gathered information from external transponders and portable equipment/meters which was summarized in Deliverable 1.4.

Task 1.4: Specification of Measurements of Biometric and Mine Atmosphere **Parameters**

In Task 1.4 the essential discussions with project partners, CSRG and DMT, took place. The following is a summary of the outcome of these discussions:

1). The proposed (estimated) data rate via the m-Comm system was acceptable to all. All sensor information was considered of equal importance and should be transmitted as soon as was practicable, i.e., no priority given.

2). DMT had selected their sensor ideas mainly from the work of the RFCS EMTECH, (2012), project and from their own mines rescue's current procedure of monitoring skin temperature, humidity, (via wet and dry bulb method), and air velocity. It was GAUK's understanding that these measurements and analysis took 7 to 10 minutes to complete.

3). DMT supported the use of a professional biometric/chest monitor made by SEM. The small multi-sensor unit is strapped across the chest next to the skin monitoring, heart rate, breathing rate, skin temperature and skin galvanic measurements that can be stored for either transmission or analysis later.

4). The SEM monitor had an option to monitor core body temperature via a radio coupling ingestible capsule 'pill'. However, there was negative feedback from the UK Mines rescue Service about the accuracy of an internal radio pill particularly when introducing the use of chilled water, via a tube in the face mask, for alleviating heat stress. Moreover, the cost of each pill was quoted as $80 per single operation.

5). On the question of linking the SEM to the m-Comm mobile unit DMT believed that of the different options the SDS (short data standard) output would be the more suitable. However, it was not known if the new generation of SEM unit had this form of output option.

6). CSRG clarified their input to the project for environmental gasses, temperature and humidity sensors (see below).

As a result of the discussions, GAUK based its data inputs on a mix of analogue and digital options. Test data transmissions were initially conducted with simple but accurate temperature and humidity sensors. Detail analyses of possible multi gas sensor portable units were undertaken that had a serial interface for extracting data which would enable the digital input option to be evaluated.

The resulting specifications are fully listed in Deliverable Reports D1.4 and D1.5, and summarized below:

- Analogue input for biometrics, body temp, humidity, etc.
- Digital for environmental, possibly serially connected from external multi sensor monitors/meter (self-powered)
- System status, e.g., sensors, wireless unit, battery condition, etc.
- Other life critical input, such as, breathing apparatus pressure (from Dragger BG4 electronic unit output) were considered as optional.

CSRG listed their requirements and specification for environmental gasses, temperature and humidity sensors including a specification for the rescue communications system, and summarized below:

- o Continuous measurement and display of gas concentrations, O_2, CO, CO_2, CH_4, temperature and humidity
- o Accuracy: dependent on the concentrations of gases:
  - ▪ O_2 – 0-25% (accuracy of approximately 0.1%)
  - ▪ CO – from 1ppm – 1000ppm to 2% (over 1000ppm to 10%)
  - ▪ CO_2 – from 0%-100% (accuracy 0.1%)*
  - ▪ CH_4 - from 0%-100% (accuracy 0.1%) *
  - ▪ Temperature : -10^{o}C – 120^{o}C
  - ▪ Humidity : 0%-100%
- o Alarm thresholds : acoustic and visual alarms
- o Working time more than 16 hours

A copy of the Polish rescue tables for work duration in hot and humid conditions was obtained and found to be similar to the German matrix for calculating maximum working time in rescue operations. CSRG specified the minimum requirement for a rescue communication based on Polish regulations/requirements:

1. Continuous two-direction communication: base - team
2. The distance required between the radiotelephone and the cable – minimum 5m
3. The maximum distance between the rescuer's radiotelephone and the radiating cable (antenna): - in the antenna axis 100 m, - perpendicularly 15 m – 50 m (depending on the conditions).
4. Call signal from the base transmitted to the rescuer's telephone
5. System of power cable status control
6. Protection against accidental turn-off or turn-on of the base transceiver
7. Communication range – the distance between rescuers and the base *circa* 2500m
8. Battery charge indicator
9. Time of work - min. 15h

Task 3.1 Development of biometric sensing and communication subsystems

The biometric parameters and other sensors identified in Task 1.4 was interfaced with the m-Comm wireless module in a way that allows for adaptability and be within the possibility of ATEX certification. To this end, the wireless module interface was developed with analogue and digital interface options. The number of sensors that can be attached or interface to the m-Comm wireless module at any one time is limited and only live tests will determine the exact number and combination. Thus, a representative number of sensors are to be tested and demonstrated with the understanding that other combinations may be possible.

The collaborative discussions with CSRG and DMT reinforced the requirement for heat stress monitoring of individual mines rescue members. Hence, DMT designed and developed three sensors as their contribution. As part of the collaborative work the DMT instrument incorporated an m-Comm Mk3 Bluetooth wireless module fitted internally. In addition, and with a separate wireless link, GAUK were to demonstrate a combined voice, temperature, and humidity monitoring system as an alternative. The temperature, humidity and possible others parameters were essential in the wider field trials of the m-Comm system, particularly, in providing real display data at the 'fresh air' base. Heart pulse monitoring was examined and a practical demonstration was made of such a device working as an example of another biosensor with the m-Comm system. However for the INREQ project it was regarded as an example of how sensors could be processed, i.e., counting the heart beats from the analogue signal, and interfaced with the m-Comm data channelling system (Fig. 51.)

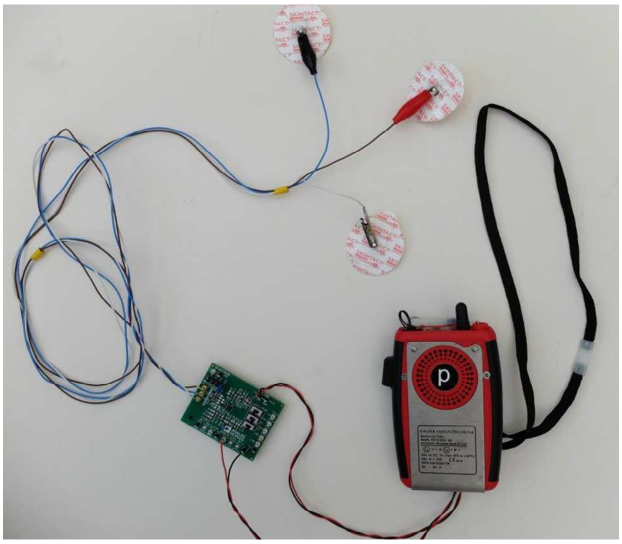


Fig.51: Heart pulse monitor interfaced with the m.Comm wireless unit

Task 3.2 Design of m-Comm Data Transfer and Capture System

The objective of Task 3.2 was to develop the necessary electronic hardware and firmware for m-Comm units to provide the following functions:

- Biometric transponder data interfacing and initial processing to minimise data transmission requirements
- Data transmission through the m-Comm system to a fresh air base unit
- Data capture at fresh air base, storage and post-processing for generation of an appropriate graphic display, warnings and alarms
- Data management for storage and archiving of measured parameters

Work began on this task based on the findings of Task 1.3. The data transfer protocol is an asynchronous 1200 baud FSK signal transmitted along the m-Comm voice line in one direction only, from Hub to Base, in 300 ms bursts. The data itself will be made up of one byte (8 bits) of Hexadecimal per sensor channel plus overhead, (e.g. start bit, stop bit, parity etc.), and buffered until a window is available to transmit interleaving the data transmission with the voice communications.

Continuous Tone Control Squelch System, (CTCSS), technology is to be used to provide separation of the voice and data signals on the shared line such that users do not hear the data transmissions and that the on-board processors do not attempt to decode voice signals as data. CTCSS was implemented successfully for the m-Comm voice channel such that when a user transmits a message, (by pressing the press-to-talk, PTT, button on their unit), a sub-audio tone is transmitted. This tone is detected by a tone-detect IC, (integrated circuit), which signals to a unit that a voice message is being transmitted and un-mutes the speaker. When no sub-audio tone is present (the default position when no user is transmitting) the m-Comm unit speakers are muted.

As the data transmission design and development effort is both complex and requires validation checks in order to produce a reliable final solution it was decided to divide the development process into 6 stages, described below.

Stage 1: Hub to base Communication

This proved to the most complex stage requiring the most innovation to counter the many problems encountered. Firstly, the original embedded PIC 16F1503 processor had to be upgraded to the newer 16F676 processor, which had increased data storage, a faster digital-to-analogue converter and other additional functions. Importantly, this upgrade enabled the PIC processor to generate and send FSK signals thus eliminating the need for a dedicated FSK chip and, hence, maintain the same 'hub' hardware layout. The schematic diagram, Fig.52.below, illustrates the modifications required to the original m-Comm hub circuit

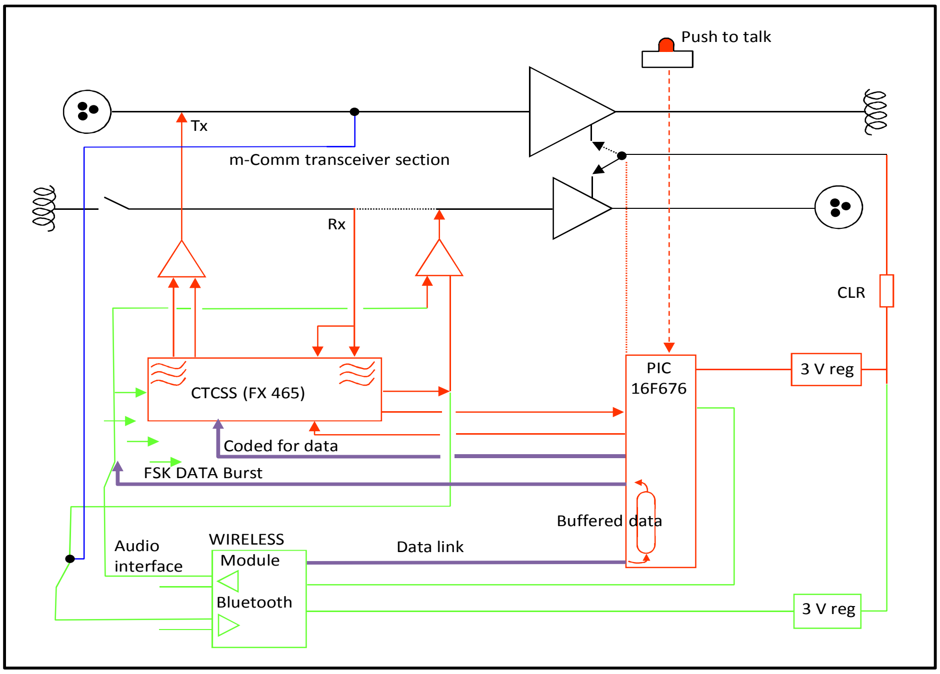


Fig.52: Schematic diagram of the wireless enabled m-Comm 'Hub' handheld Unit (The heavy purple lines show the data path from the Bluetooth wireless chip via the buffer in the PIC processor and the generated FSK modulation to the transmitter together with the CTCSS tone code)

Stage 2: Base Output Section Hardware and Interface
Stage 2 had to be developed in conjunction with Stage 1, receiving and proving the signals generated and sent from the Hub. A prototype board/module designed and made to detect and convert the FSK signal back into data revealed an unacceptable switch-on delay of nearly 500 ms from the sub-audio tone detect (CTCSS) chip. Remembering that the total data burst duration has to be kept to less than 300 ms for a workable system this was a major problem to be address. After careful consideration it was decided to develop and test the data transmission function without a second muting CTCSS tone. The original intention was to implement a second 'data' muting tone (CTCSS) when transmitting data. However, a logical analysis of the protocol concluded that if the voice channel is muted by default, signals on the line that are not accompanied by the sub-audio CTCSS tone will either be noise or data. This means that if the data processing electronics and software can differentiate between noise and actual data then the second tone is no longer necessary and hence no added mute switching delay in the data path. In addition, by operating the base circuitry with just one CTCSS chip, for voice signals only, it considerably simplified the base unit's extra data PCB.

Stage 3: Wireless link to Hub data path (no sensor inputs)
The UART facility within the new PIC processor made it easier to pass the data through the Bluetooth module. Naturally the Bluetooth module had to be configured to accommodate the UART data mode.

Stage 4 – Hub Buffering and Firmware Refinements
The algorithm for commanding forward data transmission was critical for ensuring reliable co-existence of the voice and data traffic. Therefore, in its basic form audio traffic (via PTT and un-mute) was constantly monitored and if clear a data burst was sent. After a data burst was sent there was a force delay of (currently) 4 seconds. This forced delay ensures the audio traffic more chance of instant transmissions. Laboratory and field trials determined the optimum setting for retry intervals. It was evident from initial trials that the comfort bleep, sent from the base unit at 15 second intervals, was causing the data send algorithm to accumulate extra delay. The 4 second delay may have to be altered to either be shorter or in some way synchronised to the comfort bleep. A value of less than 1 second proved reliable in simulated voice and data traffic. Firmware automatically gathered the data stream from the Bluetooth chip in the wireless interface module in the handheld or reel hub and store/buffer. At this stage, buffer overflow logic was on the basis of discarding old data for new data.

Stage 5: Sensor Interface Firmware and Hardware
The sensor interface circuits are partly located in the m-Comm wireless module and, as required, in a remote housing, as shown in Figure 6 and 7. Sensor input specification are as follows:

- 3 analogue and
- 3 digital with
- 3V power out.

Each analogue input is 3 volt (V) sensing with an input impedance of 2.2 k ohms or more. Digital inputs were again based on 3 V with zero between 0 and 0.9 V and one between 2.1 and 3 V. An external 3 V source was available for powering sensors via a 14 ohm resistor. The proposed ATEX certification is expected to require the following interface limitations:

- Vo = 4.5 V
- Io = 9mA
- Po = 10.2mW
- Lo = 438mH
- Co = 100uF

In reality the number of digital inputs can be increased and this was demonstrated using three digital output sensors connected to the one digital input of the wireless module PIC processor. It should be noted that the firmware development required for digital output sensors were particularly challenging to interface with the I²C supplied by different manufacturers.
Analogue sensor interface proved much easier to implement however analogue inputs are limited to a maximum of three with the current specification.

Stage 6: Full up-link data transfer tests and finalization
The final stage of the data transfer development had to have a programmed software package to gather, collate and display/monitor the information for the 'fresh air' based rescue team. This software was developed in Microsoft .NET 4 Visual Basic. As an initial and simplest expedient data communicates is set to be via a serial COM (RS232) port. When data is received it is immediately displayed as numbers on the screen and also trend graphed. The full history of readings is stored in a Microsoft SQL Server Compact Edition database up to a maximum size of 4 GB, sufficient for holding over 1,000,000 data records.

Different versions of the display layout can be selected in order to canvass opinions on preference and to stimulate ideas from potential users. Two examples of the demonstration displayed information can be viewed in Fig.53, below:

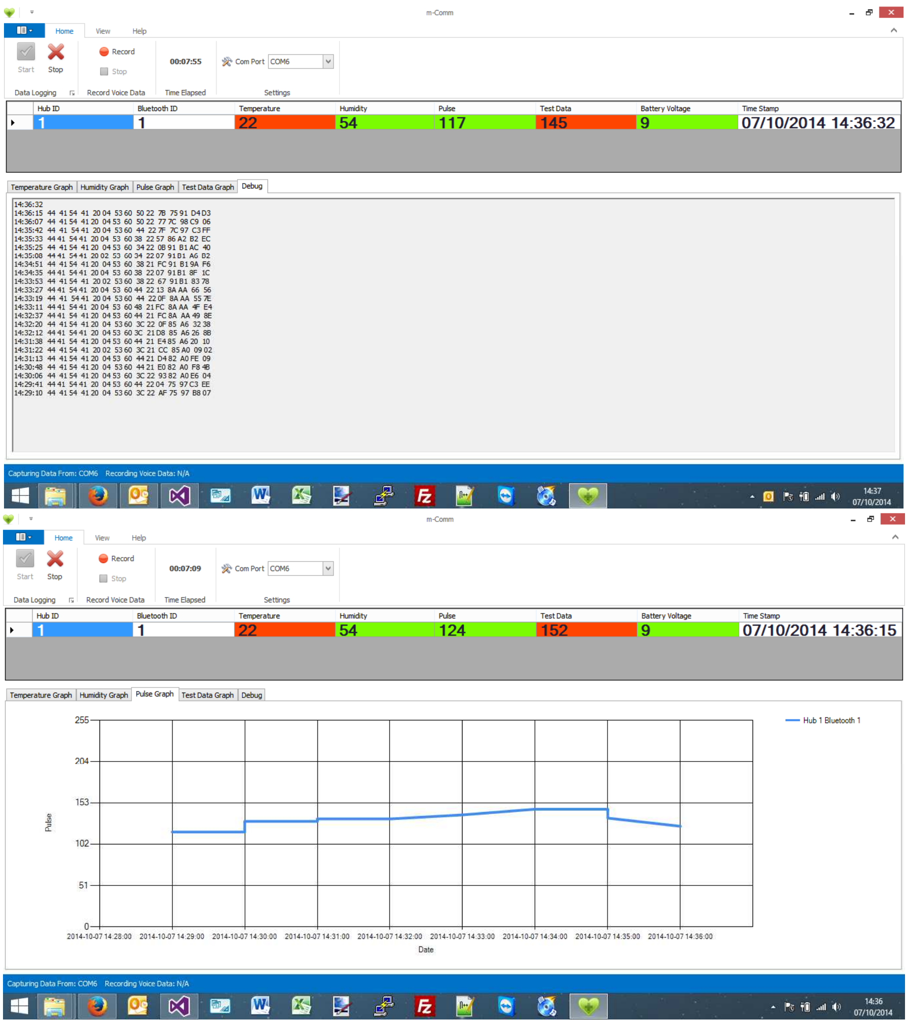


Fig.53: Example screenshot of data display software showing raw data values and graphs

Task 4.2 : Manufacture of prototype components of the system for data transfer and rescuer biometric measurement

The data transmission design and development effort was complex and required validation checks in order to produce a reliable final prototype solution; as a result it was decided to divide the development process into 6 stages. The manufacture of the prototype components is reported below in relation to the stages.

Stage 1 – Hub to Base Communications:

The prototype sub-board (Fig.54.), specifically build for Stage 1 testing, and fitted with the new PIC 16F1503 processor, was also used to generate simulated data, shown as an oscilloscope trace, below, to prove the uplink transmission path and base extra decoder circuitry. The data burst signal in this laboratory test example was a shorter version of only 110 ms.

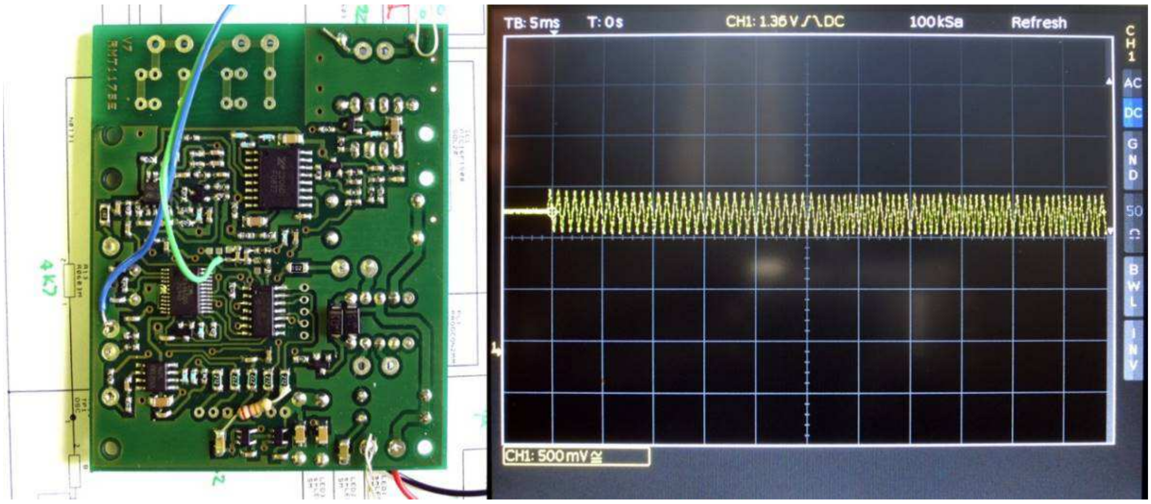


Fig.54: Test PCB for m-Comm hub transmit circuit with PIC 16F1503 processor programmed to generate 'dummy' data and encode it as FSK for sending to the surface (The 'send' FSK signal shown (right hand image) on the scope trace is transmitted along a simulated m-Comm guide wire)

Stage 2 – Base Output Section Hardware and Interface:

The base's improved data processing PCB, with its more powerful PIC 16F1503 processor, can output the data via an UART interface into serial RS232, USB, Bluetooth wireless etc. This will provide options for different means of connecting with external devices, such as, a PC or tablet computer. The new board was designed to be fitted into the existing m-Comm Base Unit and with status LED for ease of monitoring and fault finding (possibly more for the development stage than normal operation).

The prototype base board, seen in Fig.55, uses a CML Microsystems CMX469 modem chip to convert the 1200 baud FSK into a data stream to be supplied to the PIC processor. During early development an Integrated Circuit Emulator (ICE), connected by the multicolour cable, replaced the PIC processor for easier development and testing of the embedded software. Fig.55 also shows an example scope trace of the decoded FSK signal data. Fig.56 shows pre-production data board, with its optional LEDs, fixed the existing Base unit transceiver boards.

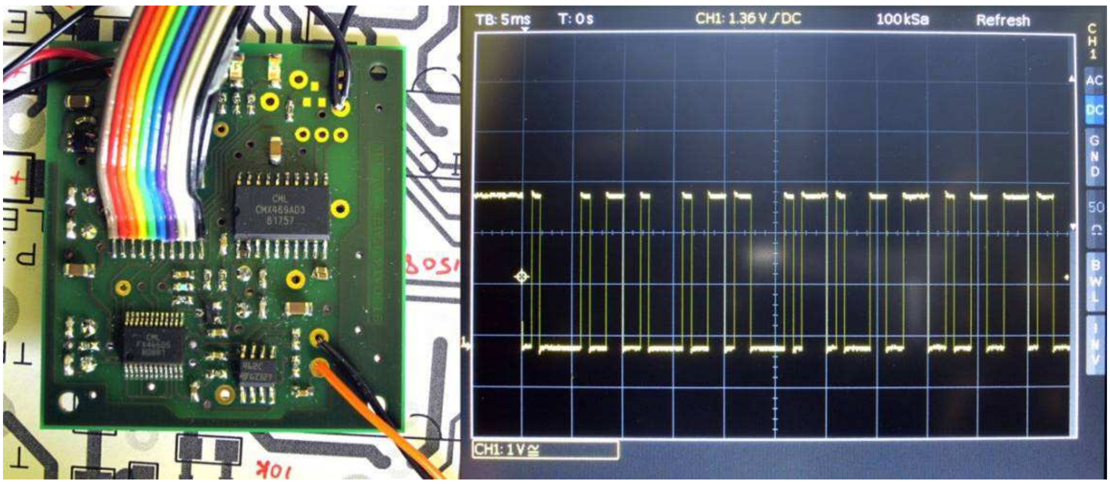


Fig.55: Working prototype board, (located in the m-Comm base unit), for decoding and output of

transmitted data (The received and 'cleaned up' FSK signal shown on the scope trace (right hand image) gives a good indication of the data/transmission quality)

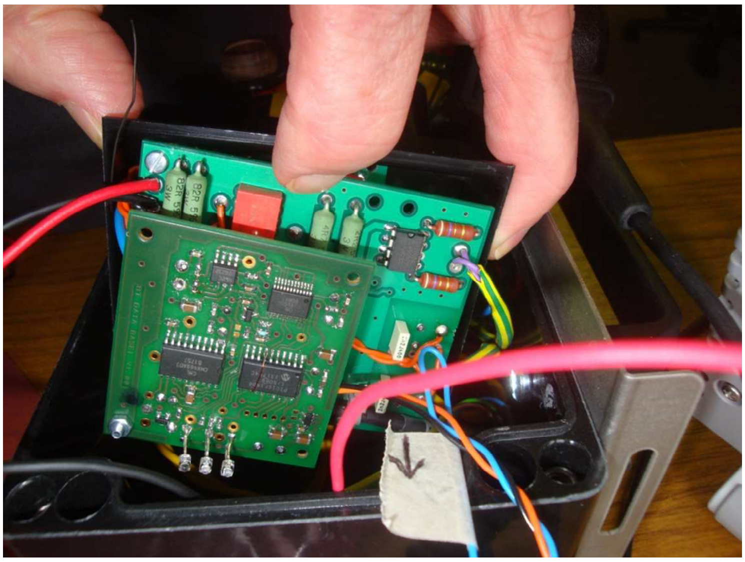


Fig.56: Pre-production Base Unit Data Board

Stage 3 – Wireless link to Hub data path (no sensor inputs):
The UART facility within the new PIC processor made it easier to pass the data through the Bluetooth module. This required the Bluetooth module to be configured to accommodate the UART data mode. Test transmissions were conducted to successfully establish data rates capability. Firmware within the wireless module packaged the data from each sensor input in a HEX form.

Stage 4 – Hub Buffering and Firmware Refinements:
Firmware automatically gathered the data stream from the Bluetooth chip in the wireless interface module in the handheld or reel hub and store/buffer. At this stage, buffer overflow logic was on the basis of discarding old data for new data. Fig. 57 shows an exploded view of the wireless module connected, via a curly cord, to sensors housed in a remote low profile case. The photograph on the right shows the paired Bluetooth interface board connected to a handheld hub.

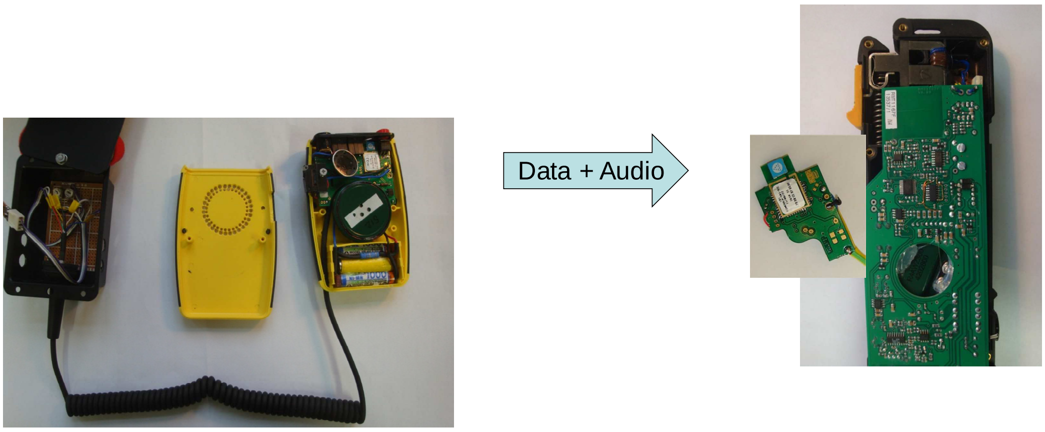


Fig.57: (Left) Wireless module connected, via a curly cord, to sensors housed in a remote low profile case, (Right) Paired Bluetooth interface board connected to a handheld hub

Stage 5 – Sensor Interface Firmware and Hardware:
The sensor interface circuits are partly located in the m-Comm wireless module and, as required, in a remote housing, as shown in Figure 4.4, above and 4.5, below. Sensor input specification was as follows:

- 3 analogue and
- 3 digital with
- 3 V power out.

Analogue sensor interface proved much easier to implement however analogue inputs are limited to a maximum of three with the current specification.

Stage 6 – Full up-link data transfer tests and finalization:
As indicated in Task 3.2 the final stage of the data transfer development was to have a programmed software package to gather, collate and display/monitor the information for the 'fresh air' based rescue team. This software was developed in Microsoft .NET 4 Visual Basic. Different versions of the display layout can be selected in order to canvass opinions on preference and to stimulate ideas from potential users.

Task 5.1: Laboratory tests of data monitoring and transfer system

Sub-system Testing:
Sub-system testing conducted separately was a major contributory factor in achieving an overall working system. After that full up link data transfer tests and finalization was conducted. Again with generated/dummy sensor data and simulated voice traffic the full system was proven to operate well within the original project specification. There was noteworthy feedback and suggestions from trials and demonstrations for improving the display information:

- Record all the m-Comm base audio on PC,
- Display the operational elapse time, also date, time,
- Relay the data (and possible audio) via telephone line to surface location,
- Wireless link to PC would be the preferred option for Base unit data interface, and
- The range of potential uses and monitoring opportunities were seen during demonstrations.

The laboratory tests and demonstrations of data and audio transmission over the modified m-Comm system proved successful and allows for a full working system to be evaluated in simulated operational conditions.

Fig.58 diagrammatically shows the original system, and Fig.59 the location of the modified prototype components.

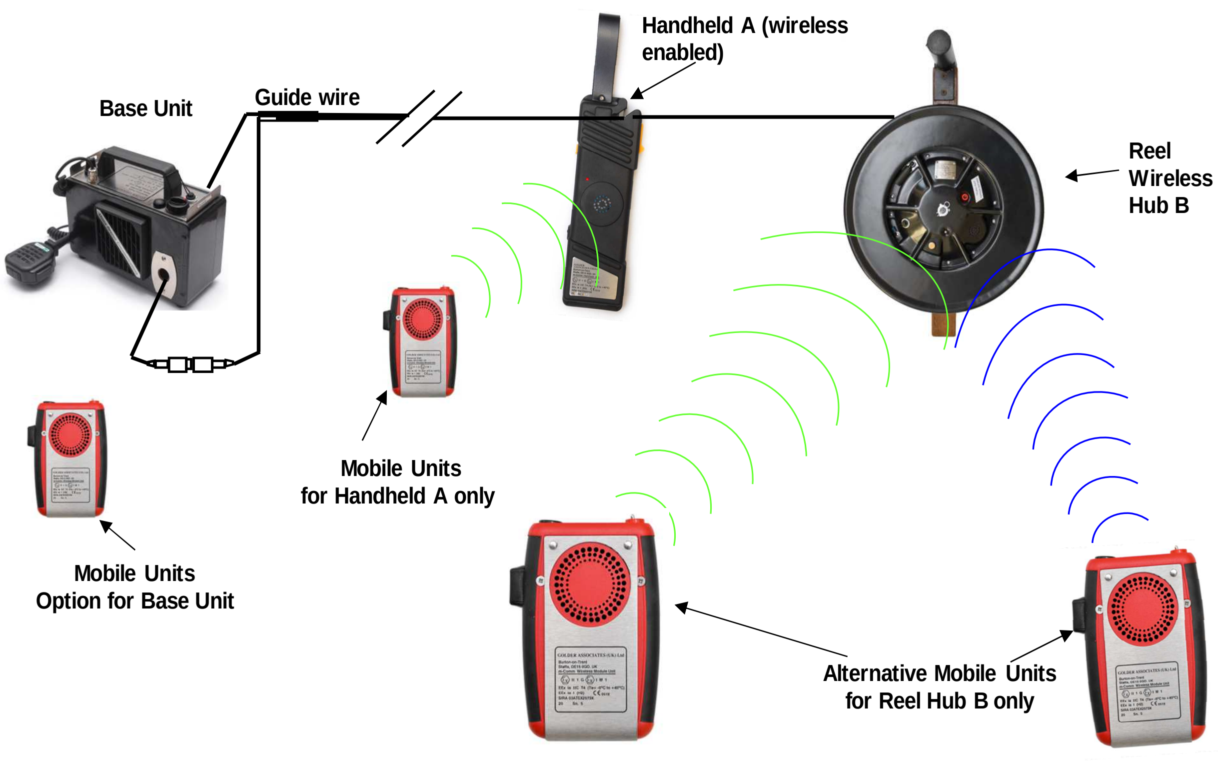


Fig.58: Diagram showing the layout of the m-Comm system

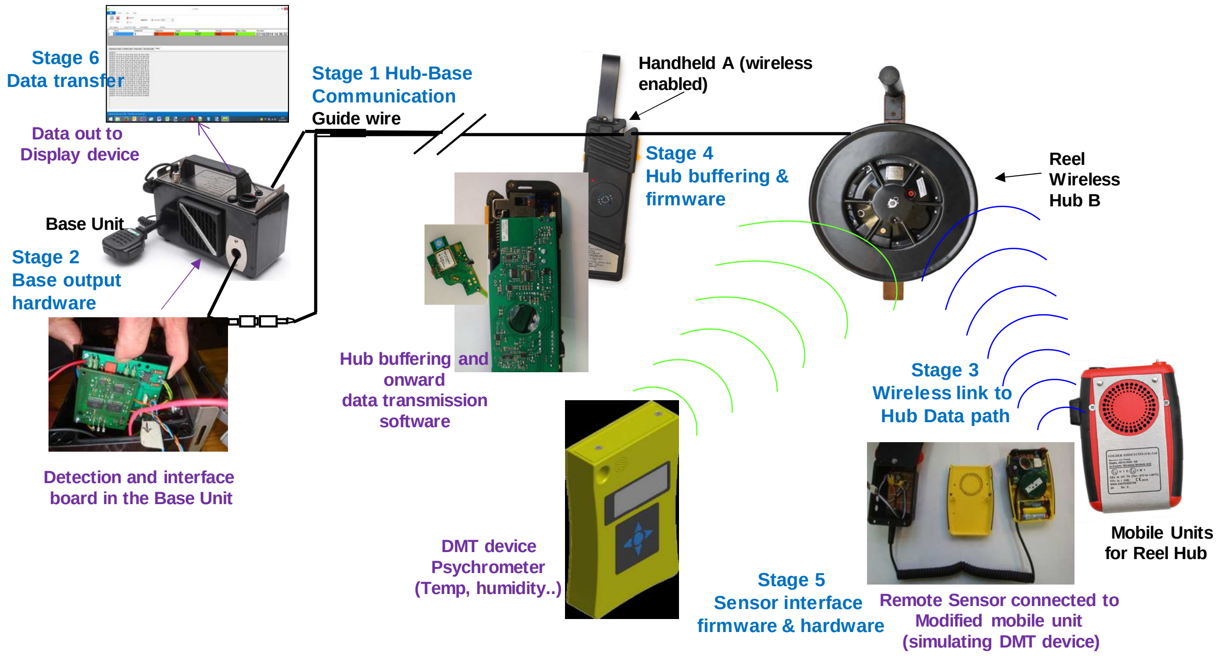


Fig. 59: Diagram showing the layout of the m-Comm system and the location of the modified prototype components

The live demonstration conducted during the 5th Progress Meeting London, October 9th 2014, further proved the system's capability and robustness (Fig.60). A heart pulse sensor was tested via the analogue channel together with a battery monitor. It was also shown that other digital sensors could be coupled up to the I2C digital input

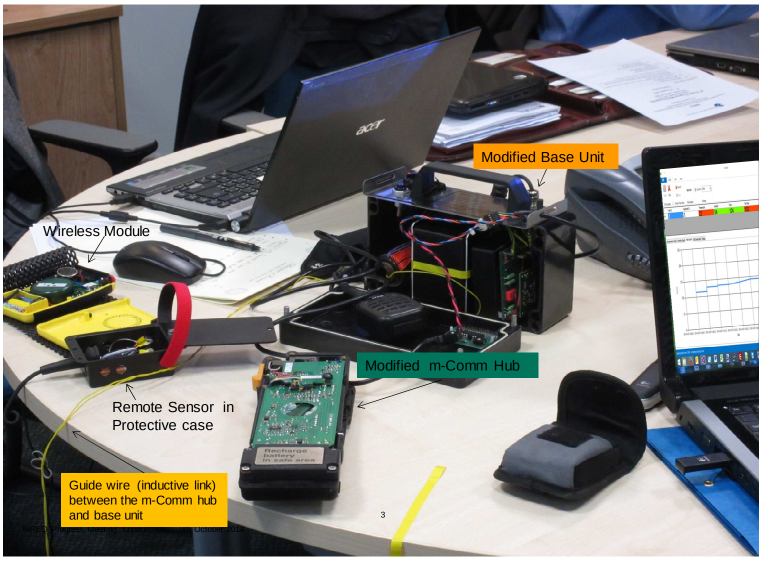


Fig.60: Photograph of the prototype system as demonstrated in the October Progress Meeting (The PC screen on the right shows the data output)

There were, however, a number of improvements that were identified as result of these full system tests. These are listed below together with later improvements and follow-ups;

Fig. 61 shows the data from a range of GAUK sensors and the DMT meter sequentially arriving at the PC. Each data line, in HEX, can be read but the important information is that both sets of data, (all the DMT reading and GAUK readings), are being received, on average, every 8 seconds, compared with the specified 5 to 10 in Task 1.3. The first group of numbers in each line is the time stamp, hours:minutes:seconds.

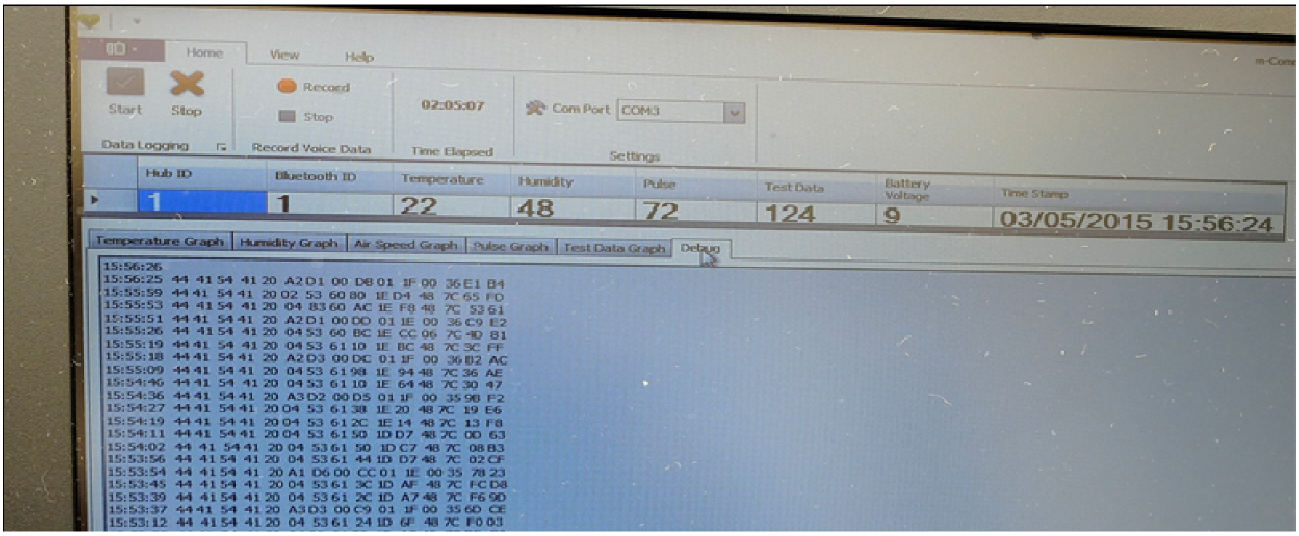


Fig. 61. Data from a range of sensors arriving sequentially at the PC

It was envisaged that the power usage with the inclusion of regular data transmission would marginally increase. In practice, this figure is dominated by the voice traffic and the extra pulsed data transmission proved to be negligible. In battery life tests conducted on the full system it was noted that, as anticipated, the hub unit had the shortest operational life but longer than the 8 hour period specified. This finding suggested that monitoring the battery voltage of the hub rather than the wireless module would be more appropriate.

The collaborative work with DMT involved the interfacing of their CMD to the m- Comm system for laboratory testing of the flexibility and adaptability of the whole new system. This DMT instrument, through pre-planning, had already incorporated space and interface circuitry for its dedicated m-Comm wireless module (Bluetooth) hence making system testing less problematic.The physical issues that needed attention in order to get the DMT instrument functional and able to communicate with the m.Comm wireless unit were:

- Voltage level conversion between the two systems,
- Aerial had to be relocated,
- The existing wireless module’s link (synchronization) indicator, LED, and
- ON/OFF, press-to-talk controls had to be removed or physically linked out.

These were discussed and agreed with DMT. Figure 62 shows the m-Comm wireless module interface with the DMT instrument during testing of:

- Data transfer,
- Power, and
- Auto-operation.

Fig.62 below shows the whole system set up and working at the GAUK laboratories.

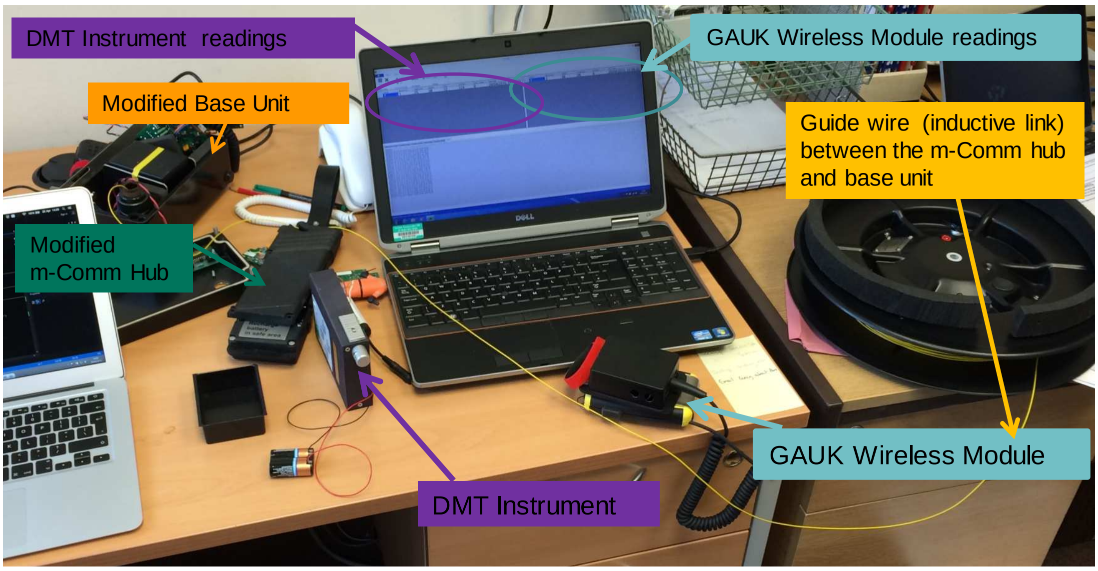


Fig.62: Photograph of the whole prototype MK3 m-Comm System including the DMT Psychometer working at the GAUK laboratories

Task 5.4: Field tests of prototype of rescue devices and communication system in mine training workings

The consortium agreed that the best opportunity to realize the task of demonstrating field testing would be during the last technical meeting of the INREQ consortium in Poland which was in April 2015. The prototype system was therefore transported to Poland and CSRG for this purpose. The reel wireless hub was used to reel out between the base station and a simulated rescue point further down the training galleries of CSRG. This demonstration showed the practical working of the m-Comm system which is directly applicable to the new MK3 prototype.
For practical purposes the reeling out of the wireless hub and simulation of the GAUK and DMT new biometric and environmental recording at a simulated rescue point was not undertaken at this time. It was more important to demonstrate the workability of the system at one location. Fig.63 shows the MK3 m-Comm prototype under test at the CSRG galleries.

Fig. 63: Field trial of the MK3 prototype m-Comm at the CSRG training galleries

The field trial was able to demonstrate that the two separate data recording wireless links instruments were able to successfully record and send information back to the base unit and portable PC as stated in the project aims and specifications in Task 1.3:

- DMT Physchometer, (for biometrics): recording temperature, humidity and air velocity in order to be able to calculate heat stress on the rescuers. This incorporated the Mk3 m-Comm wireless PCB and standard digital interface
- GAUK Modified Wireless Module: modified to be able to measure 3 analogue and interface with data channel inputs. In the demonstrations and testing of this flexible arrangement it was shown that the data channel could be arranged as a digital bus line using I2C standard, enabling it to expand the number of connected transponders/sensors. 7 sensors were successfully input via the I2C in the demonstration and testing of the system. Thus proving that the MK 3 m-Comm system could be interface with combination digital and analogue sensors, or as demonstrated with the DMT instrument, can be readily interfaced with a range of independent instruments/devices.
- That both the DMT physchometer reading and GAUK environmental/biometrics readings were being received, on average, every 8 seconds, compared with the specified 5 to 10 in Task 1.3 may be considered a major achievement given the technical difficulties that had to be overcome.

- One of main requirements placed on the development of data over the Mk 3 m-Comm system was that the voice function should not be affected in any way; for obvious safety reasons voice traffic must be available when commanded. This was repeatedly tested in a series of repeated trials of the whole (DMT and GAUK) system. No loss of voice connection was witnessed.

The field trials showed an initial bug in the software that recorded the readings from the two devices. Once an initial set of data was recorded and saved to the data base this prevented further data recording if a second session was initiated. This software bug was corrected on the return of the equipment to the UK. The MK3 m-Comm was then returned to CSRG so that they could undertake further field trials as necessary.

Task 6.1: Intrinsic safety approval of the electronic sub-systems

Under this task Partners needed to carry out tests for the conformity of their components to the requirements of the relevant directives in force. This then required the preparation of all the appropriate application documentation for submission of the equipment for ATEX and IECEx intrinsic safety approvals.

GAUK have undertaken this for the MK3 m-Comm the components consisting of the:

- Modified base unit
- Modified hand held hub
- Modified mobile unit

The MK3 m-Comm system is to be submitted for ATEX and IECEx certified Intrinsically Safe (IS) for use in hazardous areas including underground mines by SIRA Certification Service, Hazardous Area Centre, Rake Lane, Eccleston, Chester, CH4 9JN, UK. The application forms Deliverable 6.1 for GAUK.

Task 6.2: ATEX, IECEx and mining company approvals of components

GAUK were not able to submit the application for the Mk3 m-Comm within the time frame of the project. The application then required collaboration between GAUK, Trolex and the outside specialist already working for GAUK. This then needed to take into account the fact that the application had to be submitted in the name of Trolex Ltd., (all SIRA Certification licenses belonging to GAUK were sold to Trolex). A decision was undertaken to produce a thorough and detailed application to minimise the risks of rejection and/or multiple requests for amendments by ATEX. Staff at Trolex, including those in additional to staff transferred from GAUK, and the outside sub-contractor were experienced in collating ATEX applications. The detailed nature of the circuitry and complexities of subtle details in this case mean that this was considered the best course of action.

Completing the ATEX and IECEx application outside the time frame of the project was foreseeable according the page 20 of the Amended Technical Annex under section 2 Work Programme and the T6.2 task descriptor which makes it clear that full ATEX certification may not be achievable within the timescales of the project.

2.2.7. CMD - Climate Measuring Device

Climate Measuring Device was developed by DMT. In the case of work under strong thermal stress, overload to human body and a danger to health should be eliminated. Since the mines try to optimize (reduce) energy for cooling and ventilation, with shrinking number of employees, a definition of the work load becomes also more important in the mining industry. In this context several assumptions regarding the specific measurement devices were made both, for biometric monitoring of miner's body as well as for climate condition monitoring of miner's working environment.
The work on CMD device was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Task 1.1, 1.4 of WP1
Task 3.3 of WP3
Task 4.3 of WP4
Task 5.2 of WP5
Task 6.2 of WP6

Task 1.1 Determination of assumptions for prototype and experimental rescue equipment:

Thus, there exist already several measurement apparatuses used for single climate parameters in underground, but an up to now missing device with coupling possibility to emergency communication systems could be simplify the handling for measurement of such important parameters in significantly manner. Therefore DMT's objectives were to develop a measurement system that could be evaluate the momentary environment conditions of mine rescue teams with direct data transmission possibility via emergency bus-systems like "m-Comm". Especially software modules will support the officer in charge during the determination of the maximum workload of the troop-members in the case of emergency missions and incidents.
DMT worked closely with partners, especially with CSRG and GAUK. A lot of open questions were discussed during the kickoff meeting on 9th of November, 2012 in Poland. The details of the interface of GAUK's "m-Comm", the candidate of possible communication bus-system were discussed. All important functions and processes were presented by GAUK. With the outlines of those discussions and basic definitions, DMT has used this first project period to determine the requirements for candidate sensors in terms of possible electrical and mechanical adaptations. Also the later ATEX-certification for M1-category was considered here. All specifications made were then summarized within Deliverable D1.5 "Specification of the Climate Measuring Device (CMD)"

Task 1.4 Specification of measurements of biometric and mine atmosphere parameters

DMT has concentrated its work especially on the development of a measurement system that could be used to evaluate the momentary environment conditions of the working staff as well as to evaluate and suggest a maximum workload of troop-members in the case of emergency incidents. In consultation with the operation manager of German mines rescue, it was stipulated that such assessments could be achieved through the acquisition of the necessary environment parameters: temperature, air humidity, air velocity and radiant heat on the one hand and with the determination of a calculated climate index be used for determining the maximum work time under heat influence on the other. The so build up climate measuring device should then be adapted to the repeatedly mentioned m-Comm communication system in addition. Such a physiological monitoring system incorporates proprietary patented algorithms and delivers noise-free, live physiological data with meaningful interpretation. The proposed technology for use in the system will combine the measurement and wireless transmission of human physiological status information, together with movement data using an integrated tri-axial accelerometer. This offers the option to observe the body positions 'upright', 'inverted', 'prone', 'side' and 'supine', too. And with corresponding parameter-adjustment also motion measurement for being 'stationary', in 'moving' or even in 'falling' situations can be recognised. The multi-parameter monitoring system will, importantly, also attempt to measure and monitor body skin and core temperature. While the acquisition of skin- temperature will be achieved via the chest belt in directly way, the core temperature has to be measured by use of a Core Body Temperature Pill. It wirelessly transmits core body temperature as it travels through the human digestive tract. In the course of this, a quartz sensor (powered by a micro-battery) vibrates at a frequency relative to the body's temperature and transmitting a harmless, low-frequency signal through the body to the SEM. All measured data of the SEM can either be transmitted via an integrated Bluetooth adapter elsewhere or be buffered on a useable Micro-SD card for later evaluation and analyses.
For the development of the "climate measuring instrument" with an evaluation-option for the workload of rescue teams, the physical principles had to be studied. The physical condition of a healthy person is essentially determined by the climate surroundings. But the feelings of different persons are different. Therefore the decisive climate parameters: temperature, humidity and air velocity were as long as varied and adjusted in numerous measurements in the past, until the persons audited a same subjective evaluation of environment-climate within two independent climatic chambers. This point of the same subjective climate sensitivity is called "Normal-Effective-

Temperature” (NET).

In the *Table 1* the guidelines of maximum working hours are listed with fire protective clothing both, without and with cooling function (indicated in red), which were determined in numerous tests at the specified temperature and humidity values.

relative humidity (%)

dry-bulb temperature (°C)	100		95		90		85		80		75		70		65		60		55		50		dry-bulb temperature (°C)
22	80	90																					22
23	75	90	80	90									duration of deployment 90min.										23
24	70	90	75	90	80	90	85	90															24
25	65	90	70	90	75	90	80	90	85	90													25
26	60	90	60	90	65	90	70	90	80	90	85	90											26
27	55	90	55	90	60	90	65	90	70	90	75	90	85	90									27
28	50	80	55	85	55	90	60	90	65	90	70	90	75	90	80	90							28
29	45	75	50	80	50	85	55	90	60	90	65	90	70	90	75	90	80	90	85	90			29
30	45	65	45	70	50	80	50	85	55	90	60	90	65	90	70	90	75	90	80	90	85	90	30
31	40	60	40	65	45	70	50	75	50	85	55	90	60	90	65	90	65	90	75	90	80	90	31
32	35	55	40	60	40	65	45	70	45	75	50	80	55	90	60	90	60	90	65	90	70	90	32
33	35	50	35	55	40	60	40	65	45	70	45	75	50	80	55	90	55	90	60	90	65	90	33
34	35	45	35	50	35	55	40	60	40	65	45	70	45	75	50	80	55	85	55	90	60	90	34
35	30	45	30	45	35	50	35	55	40	60	40	60	45	65	45	70	50	80	50	85	55	90	35
36	30	40	30	45	30	45	35	50	35	55	40	55	40	60	45	65	45	70	50	75	50	85	36
37	25	35	30	40	30	45	30	45	35	50	35	50	40	55	40	60	40	65	45	70	50	75	37
38	25	35	25	35	30	40	30	40	30	45	35	50	35	50	35	55	40	60	40	65	45	70	38
39	25	30	25	35	25	35	30	40	30	40	30	45	35	50	35	50	35	55	40	60	40	65	39
40	25	30	25	30	25	35	25	35	30	40	30	40	30	45	35	45	35	50	35	55	40	60	40
41	20	30	25	30	25	30	25	35	25	35	30	40	30	40	30	45	30	45	35	50	35	55	41
42	20	25	20	30	25	30	25	30	25	35	25	35	25	40	30	40	30	45	30	45	35	50	42
43	20	25	20	25	20	30	20	30	25	30	25	35	25	35	25	35	30	40	30	40	30	45	43
44	20	25	20	25	20	25	20	25	20	30	25	30	25	35	25	35	25	35	30	40	30	40	44
45	20	20	20	25	20	25	20	25	20	25	20	30	25	30	25	30	25	35	25	35	30	40	45
46	15	20	20	20	20	25	20	25	20	25	20	25	20	30	25	30	25	30	25	35	25	35	46
47	15	20	15	20	15	20	20	20	20	25	20	25	20	25	20	30	25	30	25	30	25	35	47
48					15	20	15	20	20	20	20	25	20	25	20	25	20	30	25	30	25	30	48
49							15	20	15	20	20	20	20	25	20	25	20	25	20	25	20	30	49
50									15	20	15	20	20	20	20	25	20	25	20	25	20	25	50
51											15	20	15	20	20	20	20	25	20	25	20	25	51
52			deployment only in accordance with head of operation										15	20	15	20	20	20	20	25	20	25	52
53																	15	20	15	20	20	20	53
54																			15	20	15	20	54
55																					15	20	55

Table 1: Guidelines of max. working hours by using fire protecting clothes

Similar tables for different clothes, different breathing-devices, as well as different workloads are listed under Task 1.4 by INREQ partner CSRG that will underline once again the need for such policies.
All these tables, experiences and regulations of European rescue headquarters can and should be stored in the planned “climate measuring device” (in the form of a mini database) so that they can be retrieved when needed. The essential terms for the hard- and software specifications of the “CMD” was fixed within Deliverable D1.5.

Task 3.3 Development of the measurement-system for environmental parameters

Hardware determinations and developments:
Very early within the project it was of important interest for GAUK and DMT, to constitute the kind of device with regard to the later application. Here relevant situations were considered both, for offline measurements somewhere in mining working areas as well as corresponding online measurements in the case of rescue-activities with “m-Comm” equipment.

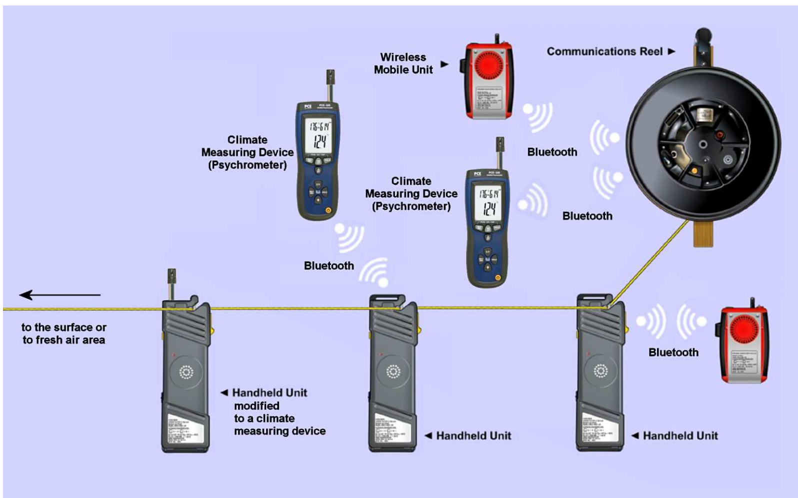


Fig.64: Considerable options of CMD-implementation in “m-Comm”

On the Fig.64 is shown, how the (not until then developed) “Climate Measuring Device” could be implemented in the mentioned m-Comm structure. For the Climate Measuring Device, the communication possibility via inductive coupling was discarded very early, because the Bluetooth-variant has the advantage, to use the device also with other bus-systems very easily.

With regard to the mechanical construction, it was considered, how the CMD device could be manufactured, with as low as possible efforts and budget and the necessary qualify for a development beyond the state of the art. For this, DMT has decided, to use the technological progress of 3D-printer and/or Laser hardening procedures for the manufacturing of the housing for the “CMD”. Next to the possibility, to construct especially forms and/or filigree individual parts, also the calculations and quotations showed that such new methods indeed could be more cost-effective than conventional ones. However, this latter coherence depends on precise preparatory design work, which has been started subsequently.

One essential point for acceptance of such a measuring and monitoring device lay in an artful and right considered design.
For this, consultations with Polish and German rescue Headquarters were held, to get the best feeling for the developments of such devices. Some of the required characteristics for the later acceptance were resumed by the partners CSRG. Subsequently these parameters were fixed in their corresponding deliverables.

Fig.65 shows first design of CMD deliberations. With the aid of this model should be demonstrated, how the development progress has been occurred.

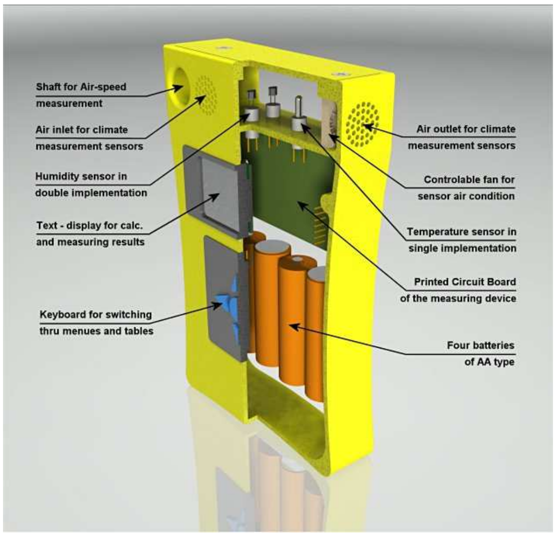



Fig.65: First design of the “climate measuring device”

Mechanical Specifications (Fixing of the housing design):

- Robustness
- Small dimensions
- Low weight
- Conditionally fire- and waterproof
- Ergonomic
- Integral within the “m-Comm“ bus-system
- Considering the dimensions of sensors and electronic

The housing should be meeting the usual mining requirements, which implies certain robustness. With regard to a required low weight, the housing material should be made of shock-resistant low-conductive plastic material or thin-walled stainless steel. The dimensions and weight are determined mainly by the size and weight of the batteries. Because it is decided to use only non-rechargeable batteries (which can exchanged only on surface), the weight of an initial planned potting compound can be discarded.

Only modest demands are made for resistance to water and fire. Tightness is desired without any requirements for special depths. Concerning fire resistance, the case should have no plastic parts, which already melt under 80°C.

The ergonomics of the device should be well planned and developed in that way, that a user or carrier has the necessary acceptance and he knows that no danger is caused by the device during a fall and that no disability will occur while wearing.

With respect to the plan, to implement the electronic Bluetooth-board from INREQ-partner GAUK, a matching place was found behind the battery-chamber. Therefore the dimensions of the housing have been assimilated correspondingly

Task 4.3 : Manufacture of prototype instrumentation for measuring mine atmosphere and system for data transfer

The CMD cooperation with m-Comm system is realized via Bluetooth radio access. This solution allows sending both speech as well as analogues measuring values to the m-Comm base station or if necessary further to the surface. This is realized by pairing the mobile unit either with the Bluetooth-adapter located within the communication reel or with the Bluetooth adapter within the gray "handheld units". As a counterpart, the wireless mobile unit (GAUK) fits a low-powered Bluetooth module as well as a corresponding One-chip Microcomputer. The latter has to detect the pauses between speech times and implement the measured data into free time intervals during transfer of speech data. Due to secure communication between rescue team leader and the officer in charge, the speech data has always the highest priority. Because of this, the MC must ensure that already measured data are buffered during priority transferring times of speech communication data. As it was agreed with GAUK, DMT was authorized to use their circuit also within the "climate measuring device".

At first a useful and ATEX-conform fan for air distribution was found and proper air-speed sensor was selected.

Assuming that the climate sensors can be exchanged or calibrated, DMT has decided to incorporate a special printed circuit board (PCB) with two temperature and two humidity sensors into one chamber within the head of the measuring device. The dimensions of this chamber were adapted to the dimensions of the fan and the remaining place near the chosen air-speed sensor.

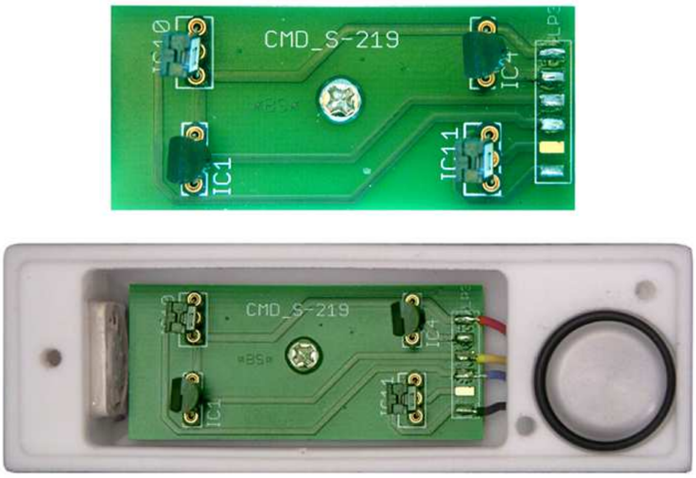


Fig.66: Printed Circuit Board for temperature and humidity sensors

In addition, a matching miniature fan, which should secure a constant slow air velocity to transfer the climate environmental data to the measuring part of the device, was selected. At constant air-flow the reproducible measurements of temperature and humidity can be guaranteed. The measuring part of the first prototype, where both the sensor board and the fan (visible on the left side) are implemented, is presented in Fig. 66.

The air-speed sensor was modified as follows:
During the first laboratory tests it became clear that the measurement of air speed with use of lead-through air channel could not be maintained. The tests in a wind channel led to more than 4% deviation in comparison with the results obtained from laboratory anemometers. Due to this, the casing geometry was significantly changed with regard to the chosen anemometer, which was integrated in the casing to be protected from dust and mechanical influences. To use this air-speed sensor a slider was installed. Thus the sensitive anemometer is telescopically extendable.
Regarding the ATEX directive, a 63 mA fuse was placed in the entry of the power circuit, while further pre-resistors in power-intensive elements caused that secure ATEX-M1 applications in hazardous underground mine areas were considered.
During the developments and tests with the first prototype of the CMD, it became clear that the up to then used Computer chip (PIC) couldn't satisfy all the necessary requirements for in/outputs, data storage and data transmission issues. So the second development step was made, where the hardware was both electronically and mechanically redesigned. The design transformation from the original device to more practical prototype of CMD is presented in Fig. 67.

Fig.67: The development-evolution of the climate measuring device (CMD)

For the keyboard only a few keys were selected to serve all the necessary functions. For intelligent programming of structural selection-menu only *up, down, left, right* and *OK* keys were necessary. Two steps of the main electronic parts are given in Fig. 68 for the purpose of comparison. The upper pictures show the boards developed for quick and simple handling, while the lower pictures show the final version of electronic CMD-hardware.

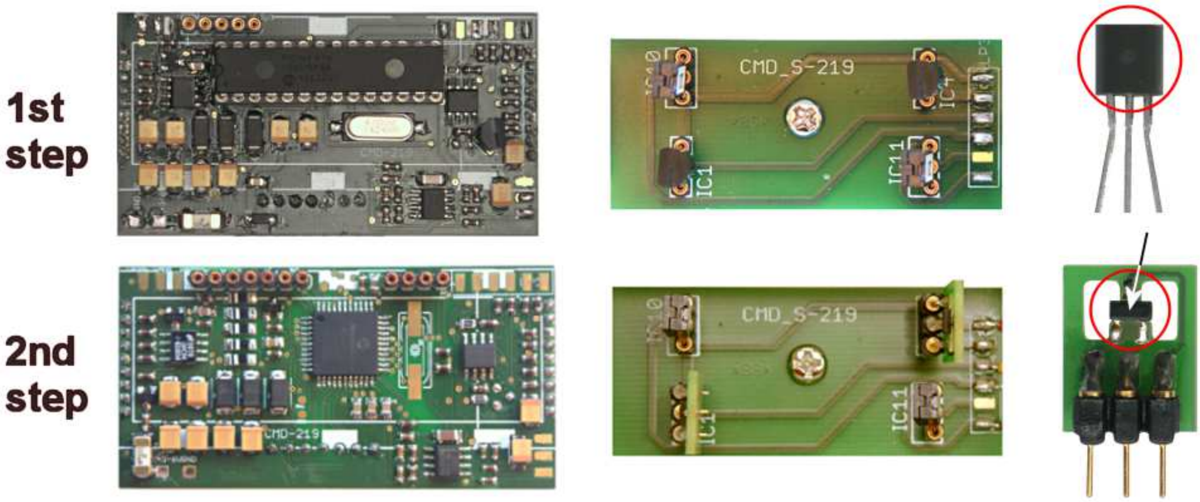


Fig.68: The electronic boards of the two-step development

Software achievements: Next to the hardware, also the considered software functions and features could be implemented into the reworked "Climate Measuring Device". Here all programmed functions (like data acquisition as well as power and display control) from *step 1* could be reused, while in the course of step 2, data manipulations, data storage and data transmission functions could be tailored to the new MC-chip.
In step 2 it became also possible, to implement hard and software for the already mentioned sensor measurement enhancement. With hardware-duplication of the temperature and humidity sensors on the one hand and the software for averaging, correlation and adjustment on the other, a more precise measurement could be achieved. This software can also be used to adjust new sensors in the case of an exchange.

New Sensor arrangements: To enhance the measurement speed of the temperature, the up to now used sensor was exchanged by a much smaller SMD-type to reduce the time of its own acclimatization. After modification, the measurement time was improved by around 50%. For a better handling, the new selected smaller sensor was positioned within a hole on a special tailored Printed Circuit Board (PCB). Only the thin connectors are soldered at the board, so that the sensor is mostly isolated from other heat (cooling) sources.

Redesigning of electronic circuits required further redesigning and development of housing. Modifications referred to strengthening the material to reach enhanced robustness of the device. Additional security glass in the display was implemented to get better robustness and sealing parameters of the display.

The dimensions were modified for:

- o better adaptation of redesigned electronic PCB,
- o better fitting-accuracy of anemometer,
- o better fitting-accuracy of planned tailored keyboard,
- o better adaptation of GAUK's Bluetooth communication board,
- o better fitting-accuracy of leather case.

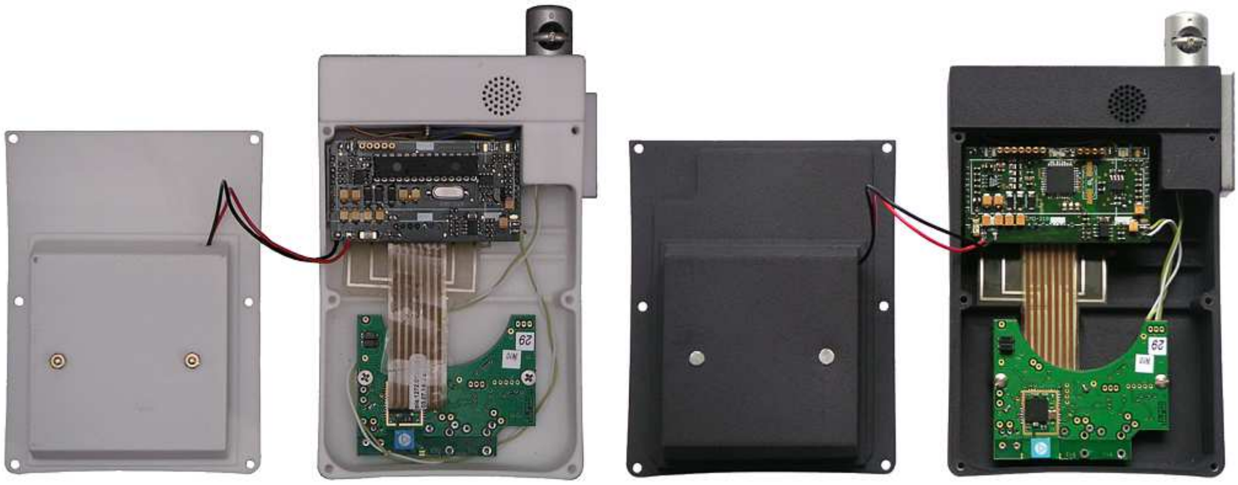


Fig. 69: Views into the opened prototypes of step 1 and step 2

Fig.69 shows the different electronic boards of *step 1* and *step 2* (in the upper section), the remaining m-Comm interface electronic board could further take place at the same position in the lower section of the CMD.
For the exactly measurement, some correlation software was implemented and this also with regard to the possible exchange of the temperature and humidity sensors. Therefore this software got its own calibration menu-point, where both, the offset as well as a linearization function could be used to implement new climate-sensors. The accurate functioning of this adjustment software was an iterating process and lasted till the end of the project. With regard to the real communication tests, the programming issues between GAUK and DMT were exchanged.
The outstanding tests were then carried out at CSRG's training working on the second day of the INREQ final meeting. With support of DMT's Climate Measuring Device, the functionality of GAUK's communication system, including transfer of operational data via initial speech-based m-Comm bus system, was confirmed.

CMD with its dedicated leather case is presented in Fig. 70. Some modifications, including mechanical extension of slider mounting bar, were made both in the device and leather-case to enable quick removal of this device from the case.

Fig.70: CMD with tailored Leather-Case

Task 5.2: Laboratory tests of prototypes of rescue devices and experimental devices

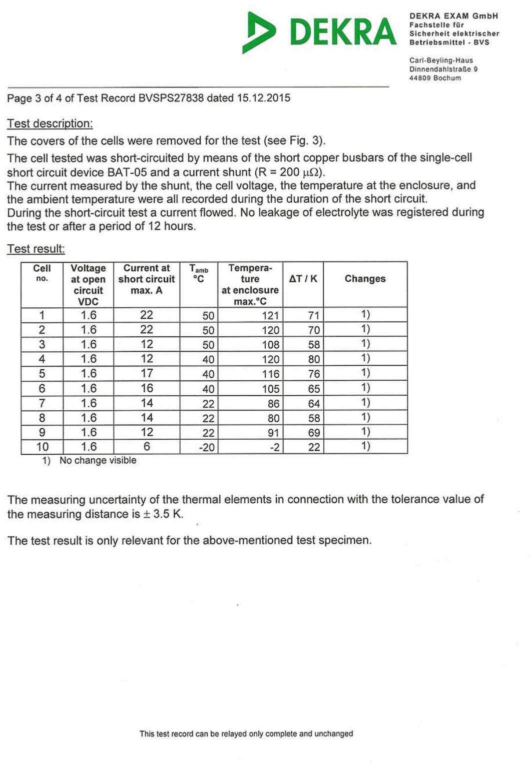
DMT planned to develop a practicable calibration test for the selected anemometer within the task. Such adjustment procedures are the precondition for precise monitoring of the climate parameters. Precise and repeatable measurements and continuous calibration procedure were necessary for the anemometer. Existing calibration device from one of DMT departments, involved in the assessment

of building security on the surface, was used. This devicewas subjected to repeatable adjustments to meet the Quality Management directives.
The calibration process as well as adjustment procedures for temperature and humidity sensors were the basis for precise Quality Management System.

T6.2 ATEX, IECEx and mining company approvals of components

How it was stated, the whole electronically equipment follow the strong directives of ATEX-M1. Thus, during all electrical specifications and developments, the ability of ATEX-certification has been regarded ever. And especially for an intrinsically safe equipment of category M1, the most stringent standards for mining application had to be taken into account.

In the course of the INREQ-project, all development work on the "Climate Measuring Device" were discussed with the office of admission and been adjusted to the mentioned directives of ATEX-M1 in parallel. The mainly points of the certification process has been documented within Deliverable D6.4. The CMD has gotten an ATEX certificate of "I M1 Ex ia I Ma" with Nr.: BVS 15 ATEX E 118



DEKRA

DEKRA EXAM GmbH
Fachstelle für
Sicherheit elektrischer
Betriebsmittel - BVS

Carl-Beyling-Haus
Dinnendahlstraße 9
44809 Bochum

Page 3 of 4 of Test Record BVSPS27838 dated 15.12.2015

Test description:

The covers of the cells were removed for the test (see Fig. 3).

The cell tested was short-circuited by means of the short copper busbars of the single-cell short circuit device BAT-05 and a current shunt (R = 200 μΩ).
The current measured by the shunt, the cell voltage, the temperature at the enclosure, and the ambient temperature were all recorded during the duration of the short circuit.
During the short-circuit test a current flowed. No leakage of electrolyte was registered during the test or after a period of 12 hours.

Test result:

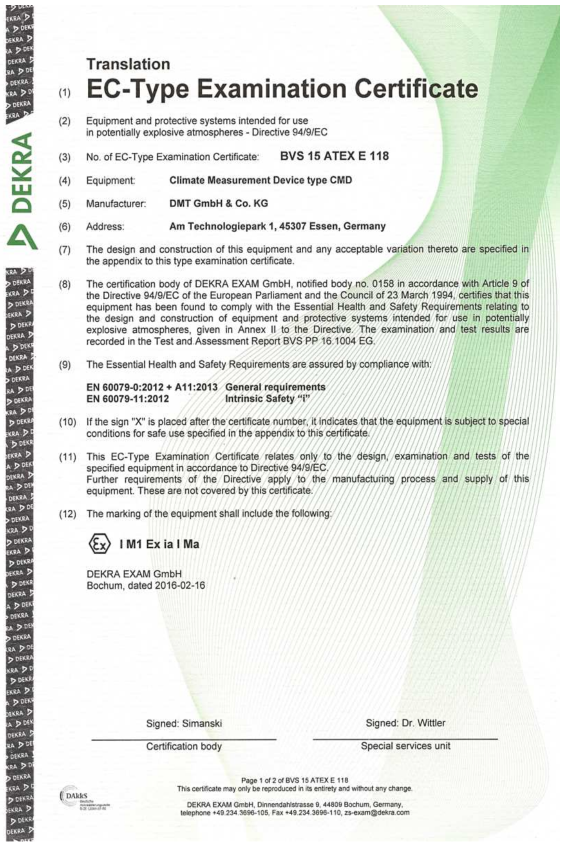
Cell no.	Voltage at open circuit VDC	Current at short circuit max. A	T_{amb} °C	Temperature at enclosure max.°C	ΔT / K	Changes
1	1.6	22	50	121	71	1)
2	1.6	22	50	120	70	1)
3	1.6	12	50	108	58	1)
4	1.6	12	40	120	80	1)
5	1.6	17	40	116	76	1)
6	1.6	16	40	105	65	1)
7	1.6	14	22	86	64	1)
8	1.6	14	22	80	58	1)
9	1.6	12	22	91	69	1)
10	1.6	6	-20	-2	22	1)

1) No change visible

The measuring uncertainty of the thermal elements in connection with the tolerance value of the measuring distance is ± 3.5 K.

The test result is only relevant for the above-mentioned test specimen.

This test record can be relayed only complete and unchanged



DEKRA

Translation

(1) EC-Type Examination Certificate

(2) Equipment and protective systems intended for use in potentially explosive atmospheres - Directive 94/9/EC

(3) No. of EC-Type Examination Certificate: **BVS 15 ATEX E 118**

(4) Equipment: **Climate Measurement Device type CMD**

(5) Manufacturer: **DMT GmbH & Co. KG**

(6) Address: **Am Technologiepark 1, 45307 Essen, Germany**

(7) The design and construction of this equipment and any acceptable variation thereto are specified in the appendix to this type examination certificate.

(8) The certification body of DEKRA EXAM GmbH, notified body no. 0158 in accordance with Article 9 of the Directive 94/9/EC of the European Parliament and the Council of 23 March 1994, certifies that this equipment has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres, given in Annex II to the Directive. The examination and test results are recorded in the Test and Assessment Report BVS PP 16.1004 EG.

(9) The Essential Health and Safety Requirements are assured by compliance with:

EN 60079-0:2012 + A11:2013 **General requirements**
EN 60079-11:2012 **Intrinsic Safety "i"**

(10) If the sign "X" is placed after the certificate number, it indicates that the equipment is subject to special conditions for safe use specified in the appendix to this certificate.

(11) This EC-Type Examination Certificate relates only to the design, examination and tests of the specified equipment in accordance to Directive 94/9/EC.
Further requirements of the Directive apply to the manufacturing process and supply of this equipment. These are not covered by this certificate.

(12) The marking of the equipment shall include the following:

I M1 Ex ia I Ma

DEKRA EXAM GmbH
Bochum, dated 2016-02-16

Signed: Simanski — Certification body
Signed: Dr. Wittler — Special services unit

Page 1 of 2 of BVS 15 ATEX E 118
This certificate may only be reproduced in its entirety and without any change.
DEKRA EXAM GmbH, Dinnendahlstrasse 9, 44809 Bochum, Germany,
telephone +49.234.3696-105, Fax +49.234.3696-110, zs-exam@dekra.com

Fig. 71: Certificate of "I M1 Ex ia I Ma" BVS 15 ATEX E 118 of CMD device

2.2.8. Virtual Simulations by Geocontrol and KOMAG

The work was carried out by Geocontrol and KOMAG. The aim of virtual animations is to help rescuers to understand the principle of operation of devices. The animations can be helpful in training the rescuers and it is their main objective.
The work on CMD device was realized within the workpackages and tasks of the Technical Annex, presented in the section 1 "Final Summary". The related tasks are as follows:
Task 1.2 of WP1
Task 2.3 of WP2
Task 3.4 of WP3
Task 5.5 of WP5

Task 1.2 Initial 3D modelling of equipment

Created models of devices were delivered to GEOCONTROL and they enabled initial verification of these devices through virtual visualizations. The first videos of the mounting support system was performed. A preliminary video showed the disposition of the legs commanded through the lever, but the command did not correspond to the real operation. On a second version of the video, it is shown the placement of the two legs on an uneven terrain, at a distance of 1.000 mm. Then, with the lever, one of the legs is extended, 10 mm with each lever movement. In the video, all the distances are shown so anyone can easily understand the dimensions of the equipment and how it will perform on field.

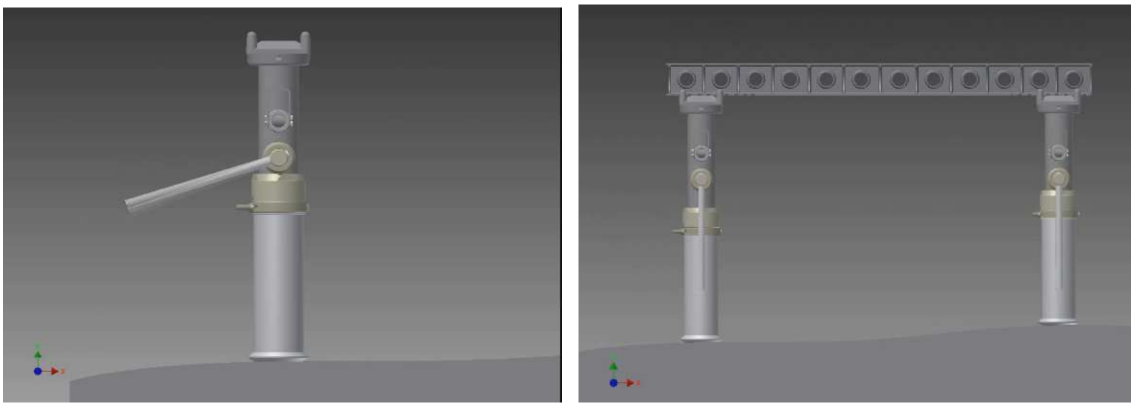


Fig.72: Video frame showing the extension of the hydraulic leg and the legs with canopy

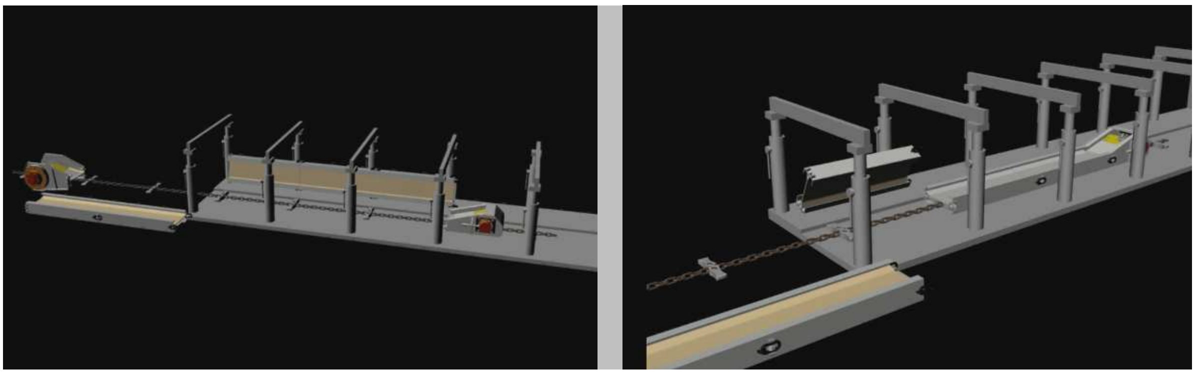


Fig.73: Pictures taken from the virtual simulation prepared by Geocontrol

Task 2.3 Virtual simulations of rescue action with use of models of rescue equipment

Gaining the knowledge on real realization of work from mine rescuers and persons responsible for trainings and carrying out the rescue actions was a significant part of work within that task. Participatory designing method, in which use of information technologies (virtual reality and augmented reality) enabled gaining opinions on design solutions at their early stage, was used for that purpose.
All analyses were made on the basis of virtual models presenting design of each component at a given stage of analysis.
3D models of working environment elements are necessary for analyses of their correlations in newly designed technical solutions. Working environment of mine rescuers is difficult to be recreated in a form of 3D model because most often it is the result of natural factors action (bump, rock fall). Development of tools helping to reach buried part of the roadway (e.g. to get to injured person) in the shortest possible time is the task objective. Models of technical means

necessary for realization of task, such as hydraulic legs, conveyor drive, conveyor troughs, transportation car, air conditioner, etc., were acquired directly from the designing process, from designers of each assembly. Arrangement of elements against each other is the result of consultation with the users. Initial model of rescue roadway, including all main components of the system, is presented in Fig.74.

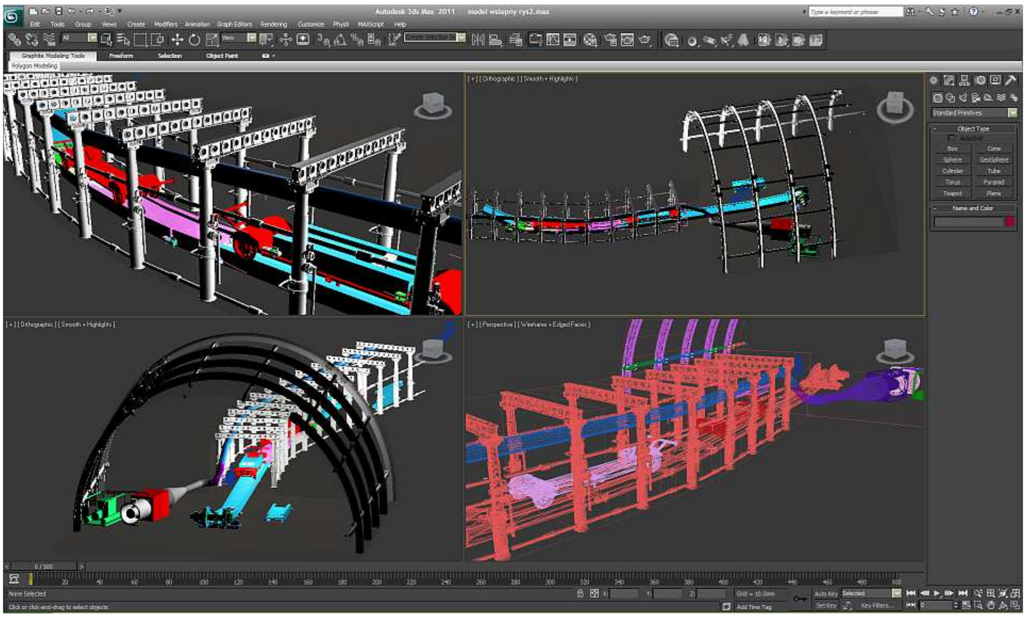


Fig.74: Model of rescue roadway

Besides technical means, which are the input to further analyses of working environment, also human factor and natural factors, which can affect available space at the workplace, should be taken into account. Human factor was included in the model by use of parametrical models of human silhouettes available in Anthropos ERGOMax software programme.
Due to the fact that equipment of rescuer (bottles with oxygen, mask, lamp) significantly increase his size, what is of special importance in the case of limited space, it was decided to replace the standard parametrical model with the model including additional clothing accessories. Development of the model was preceded by photo footage recorded in CSRG, Fig. 75.

Fig.75: Photographs of standard accesories of mine rescuer equipment

3D scene showing digging in the rock rabble was prepared to present a sample scenario of rescue action associated with digging out the gob, Fig. 76

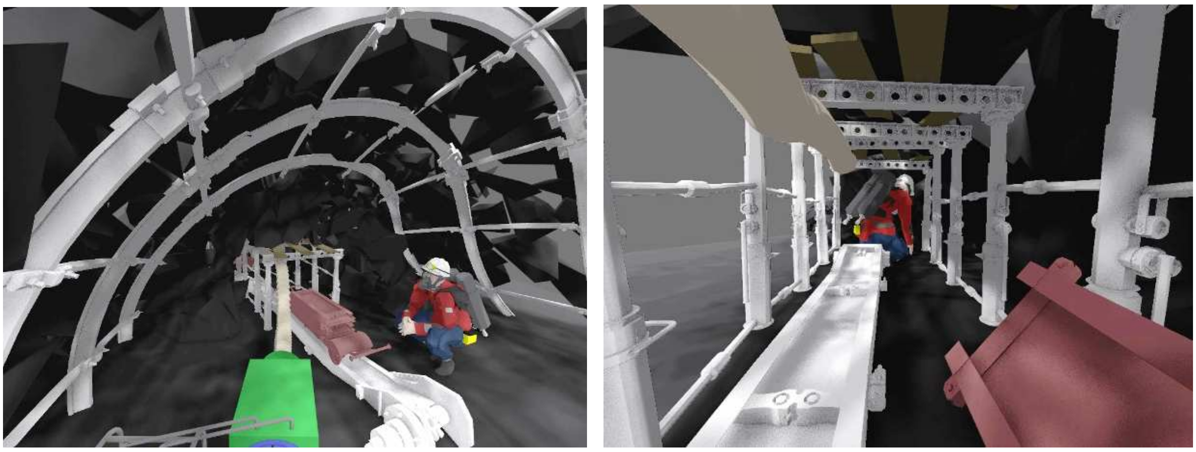


Fig.76: Model of rescue roadway including the elements of natural environment

Development of 3D model of scene presenting all elements of working environment of mine rescuers (for rescue action associated with roof fall) will be the basis for further work aiming at determination of functional parameters of each technical mean, Fig.77.

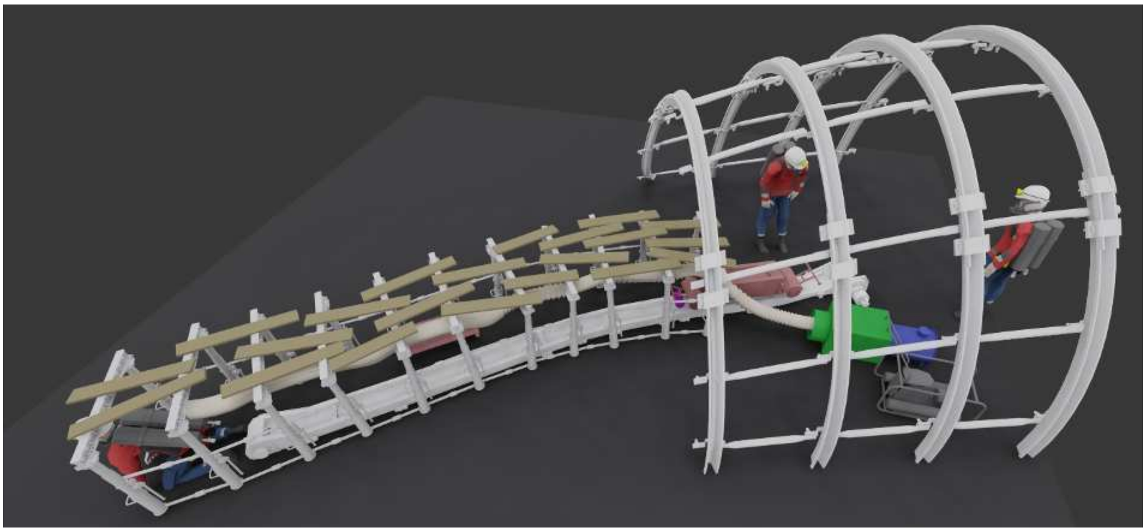


Fig.77: 3D model of rescue roadway – for rescue action associated with roof fall

Developed model will be used also in further work within task 5.5 for development of training materials associated with newly designed tools. The example of modelling the rescuer on the shuttle platform is shown in the Fig. 78

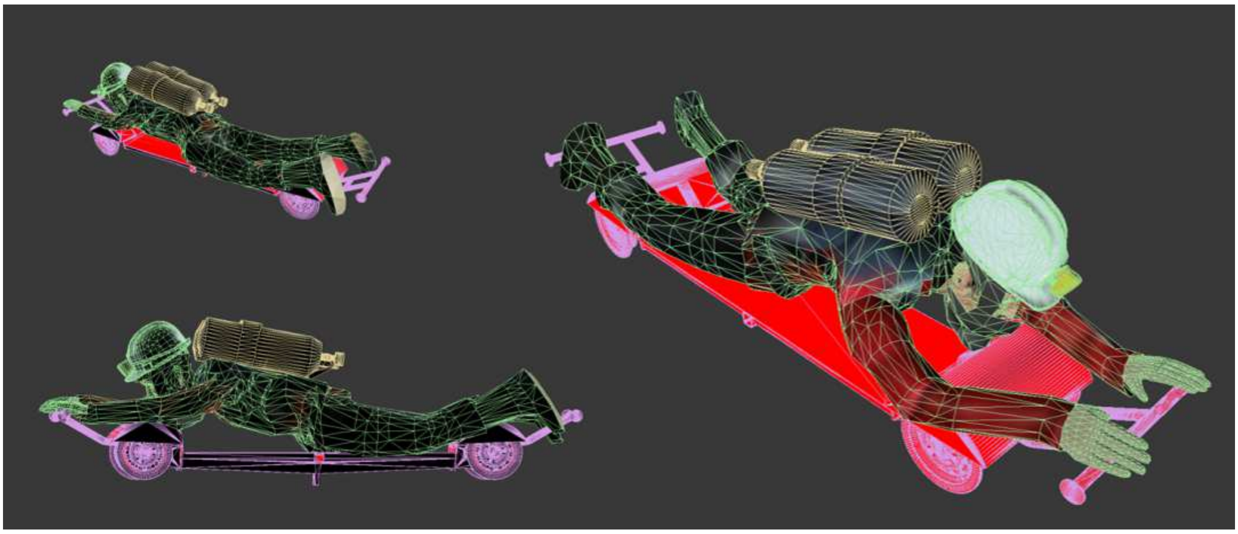


Fig.78: 3D models to analyse rescuers position on the shuttle platform

3D models of the analyzed structures displayed in 3D Studio MAX environment in an interactive mode were the basis for performed activities. Such approach enabled to include parametrical model of man in the presented interactive analyses to verify instantaneously the suggested solutions as regards assessment of anthropotechnical relationships and possible collision. Screen prints of models used during the session, including selected aspects of rescue action, are presented in Fig.79

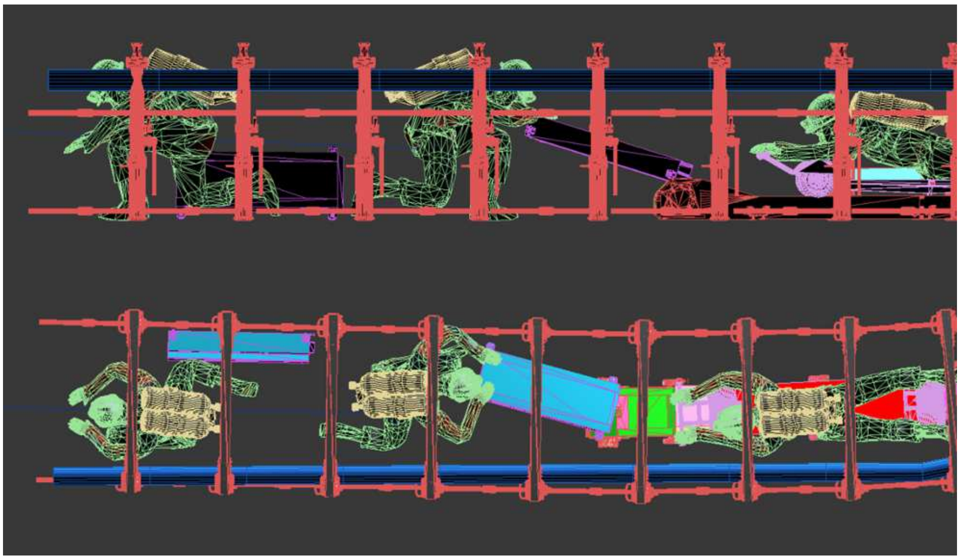


Fig.79: 3D models used for presentation and analysis of selected technological activities

Activities presented above had a form of meetings where representatives of parties discussed each aspect of analysis.

Access to the present versions of design solutions in off-line mode enables experts to analyze the suggested solutions. Additional software programme is not necessary for analysis, and presentation in a form of animated models enables people not involved in designing process to understand the process.

Preparation of the prototype to identify real operational parameters and to eliminate possible designing errors is one of the stages of designing the new solutions.

Ergonomics and its impact on the effort of skeletal system of rescuers are one of the analyzed aspects of the developed design solutions. Examples of initial analyses of static discomfort for the selected workplaces during rescue action are presented below, Fig .80 and 81.

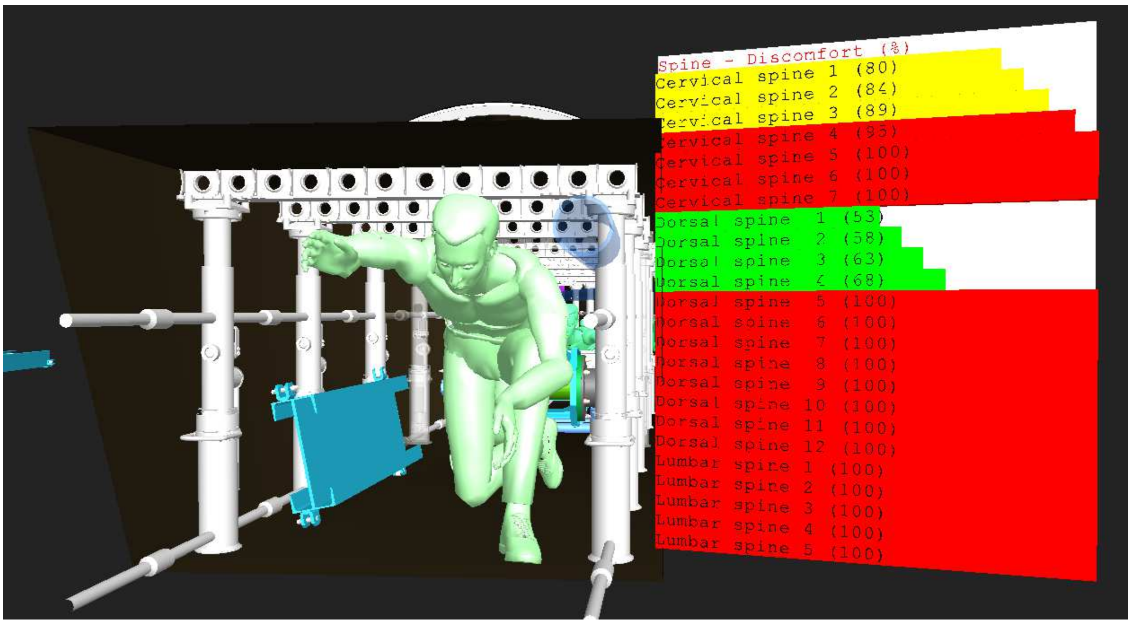


Fig. 80: Static discomfort in a spine – workplace: face of rescue roadway

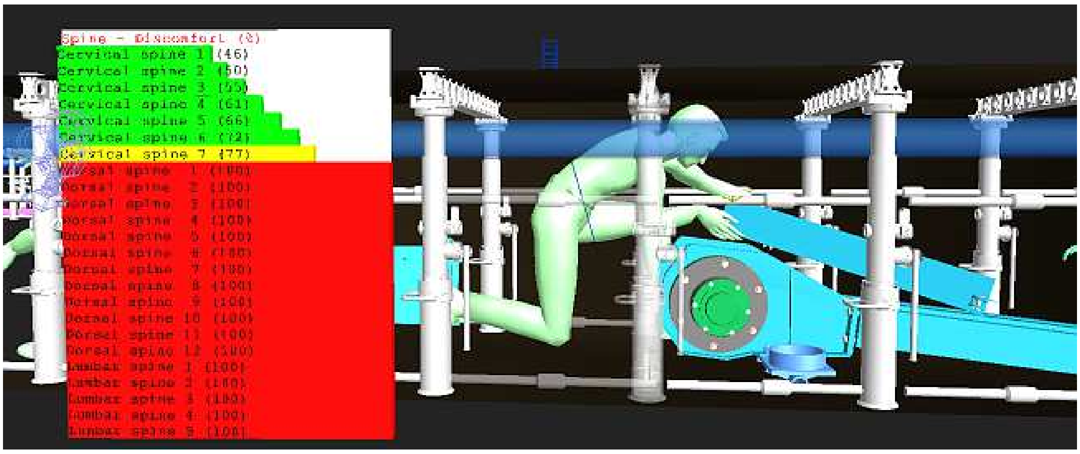


Fig.81: Static discomfort in a spine – workplace: rescue roadway

From initial eronomic analyses of selected activities it results that permissible loads to the spine are significantly exceeded at each analyzed workplace. This is mainly a reason of significantly limited working space that makes taking proper body postures impossible. There is a series of recommendations as regards proper manual transportation. However, they refer to those types of work, where it is possible to take proper body posture.

3D models of the analyzed structures displayed in 3D Studio MAX environment in an interactive mode were the basis for performed activities. Such approach enabled to include parametrical model of man in the presented interactive analyses to verify instantaneously the suggested solutions as regards assessment of anthropotechnical relationships and possible collision. The example of this analyzing is shown in Fig 82.

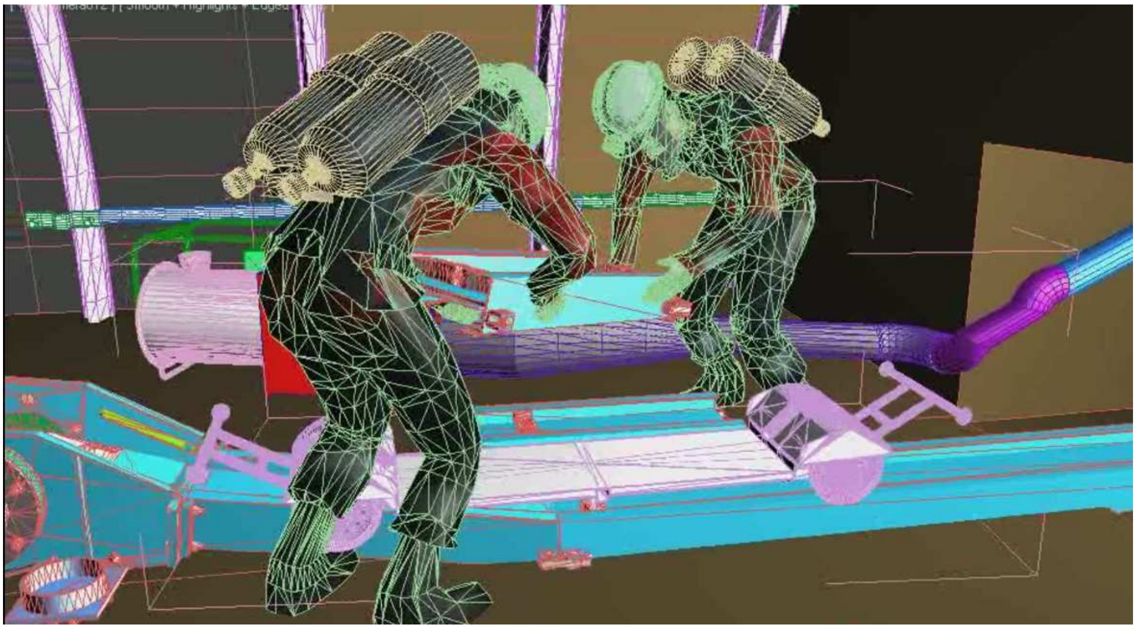


Fig.82: 3D models used for analysis of selected anthropotechnical relationships

Geocontrol prepared two types of instructional video, which is helpful to understand mounting the conveyor and rescue support during tunnelling. The first type of video is so called self-mounting, without the rescuer's activity. The second type shows the rescuers during the installation of equipment in the underground, where the accident took place.

Basing on models prepared by KOMAG, Geocontrol has continued virtual simulations regarding problems of mounting of the equipment. KOMAG also prepared some 3D analysis of selected anthropotechnical relationships. Examples of Geocontrol's simulations are shown on the Fig. 83 and 84.

Fig.83: Pictures taken from second virtual simulation preopared by Geocontrol

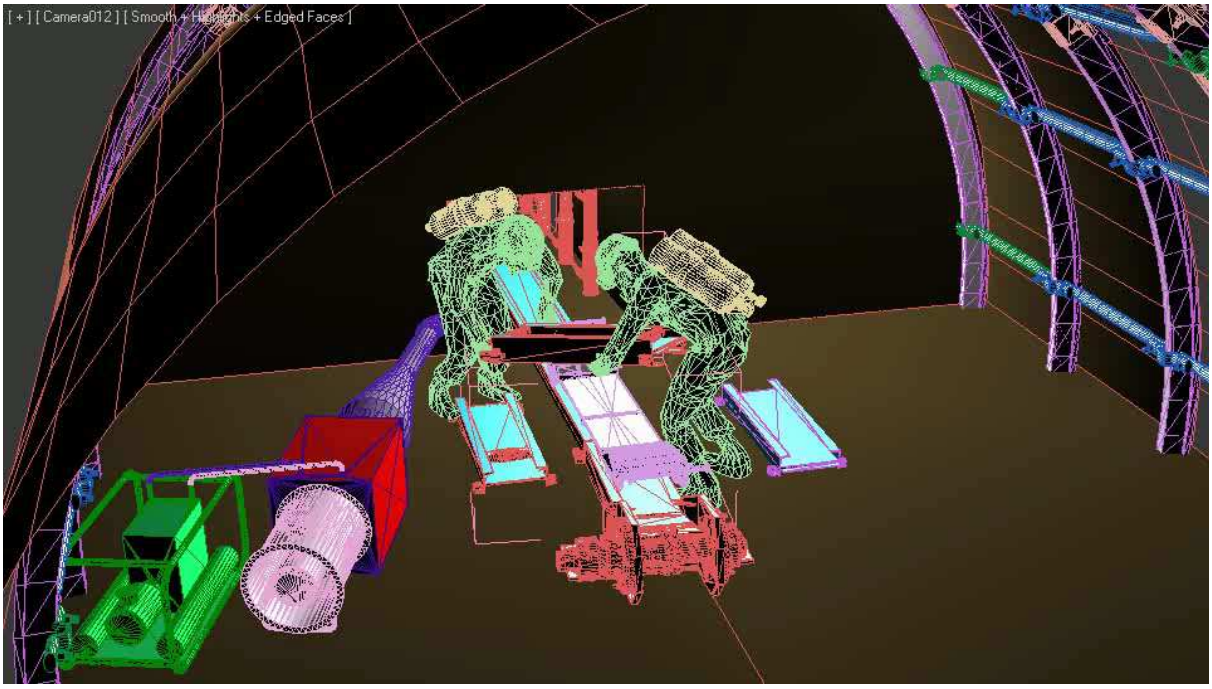


Fig.84: The example of visualization of rescue action - air conditioner, conveyor's drive and rescuers placing the troughs on the shuttle platform are shown

The aim of the task was to present in an easy way the steps that have to be followed during rescue action, with use of the rescue equipment proposed in the framework of this project.

In the final version that has been carried out, miners represented in the simulation have been animated with motion capture technology, and the main movements in the scene action are expected to be achieved.

All rescue activities are presented in a how-to-do-them way in a step by step mode. All movement will be as realistic as possible, within the objectives of the Task.

Phases of the simulation:
The program has been used to clarify all the steps to be followed when it is necessary to carry out a rescue operation, with the following steps:

1. Mounting of the first rescue support:
First structure is installed in the place where it is desired to start withdrawing material. Every structure is, at the first moment, compacted, in such a way that it requires the minimum space possible.
2. Removal of debris:
As the process goes by, more material is withdrawn and, thus, it is possible to advance forward. This way, more and more units are placed until a moment when the withdrawal of material gets much more complex, when 6 units are already placed

3. Mounting of the first group of rescue supports
The global infrastructure is prepared to continue with the installation of the conveyor, under the six units, whose aim is to continue with the withdrawal of material more easily.

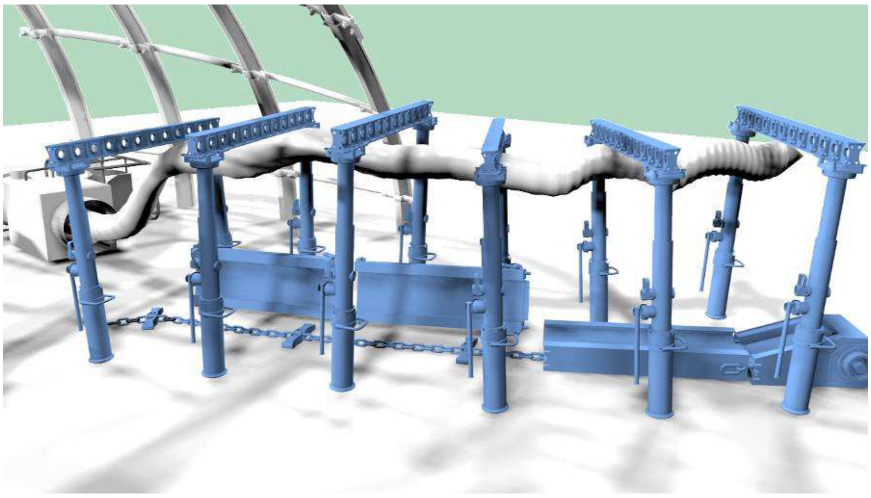


Fig. 85: The first group of rescue supports enabled to start of mounting conveyor

4. Mounting the conveyor
Several pans are placed in a row under the support structure, with a return end piece close to the point of withdrawal and a drive end in the beginning of the infrastructure.
Then, the chain is placed under the conveyor and it is attached to both the return end and the drive end element. This allows the chain to move in the direction of the conveyor.
After that, the trolley is placed on the conveyor and attached to the chain, which allows moving itself along the conveyor route. In this way, it is possible to continue the task of removing the debris from the collapse zone and continue advancing. The Fig. 88 shows the procedure to be followed:
5. Removal of next debris:
The removal of the debris is one of the tasks involved in the whole rescue operation. This allows having space for the operation to advance. The material is extracted and put away from the rescue team.
6. Advancement of the mounting of the next parts of the conveyor
As the removal of the debris goes by, the area at the ultimate section is being cleared from obstacles and, thus, more structures are due to be placed there.
The conveyor is employed to transport the legs and the canopy of every structure to the cleared area and the installation of the structure takes place. As time goes by, the operation involving the withdrawal of the material and the subsequent installation of the structure goes forward.

As a result of all the activities carried out in Task 2.3, a Video of the Virtual Simulation of Rescue Action with use of Models of Equipment was developed.

Task 3.4: Extension of virtual simulations of rescue actions by communication, measuring and data transfer systems

After analyzing the most likely scenarios in which may occur accidents related with the INREQ project, several simulation with rescue process have been developed, taking a real mine as simulation model.

Simulation Program
The simulation program, STEPs, was specially designed to simulate the movement of people both in normal conditions and during an evacuation in buildings, shopping centres, underground stations and tunnels.
The default calculation bases of STEPS are taken from NFPA 130: Standard for Fixed Guideway Transit and Passenger Rail, but modifications on passengers' behaviour can be made during evacuation process.
STEPS allows creating a very precise 3D model from the scenario, where the evacuation takes place, besides the occupational load and the evacuation parameters. The geometry design accurately reflects the level 850, with the emergency happening in "Gallery A"; where the exploitation was deployed in December 2009, as it is shown in Fig. 89

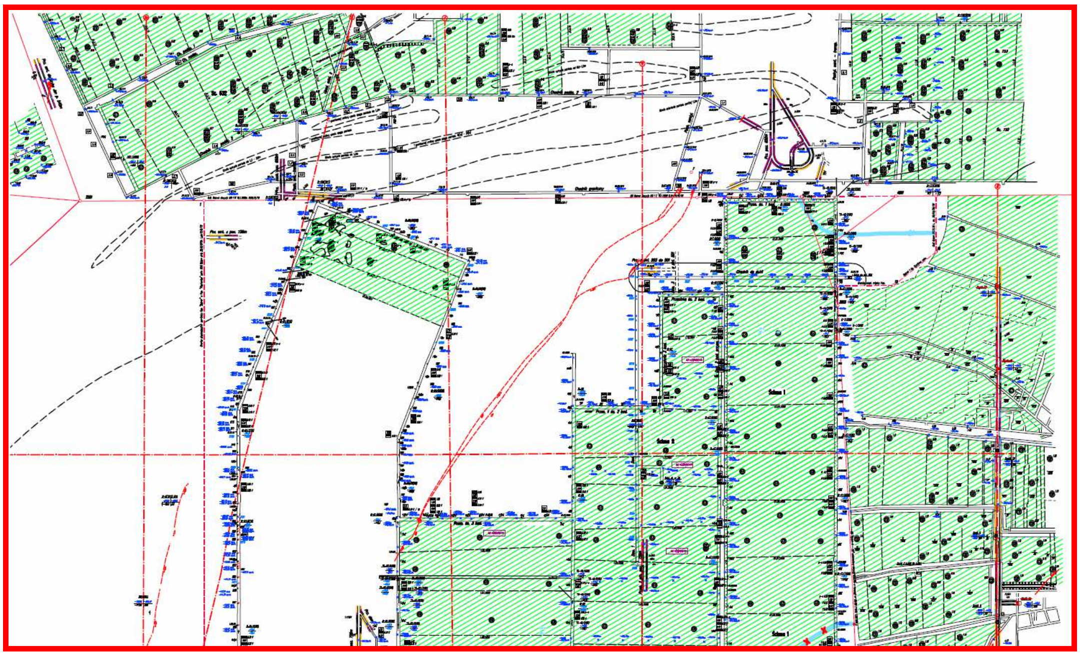


Fig. 86: Level 850 of the mine - map used in simulation

Simulation Inputs

The expected number of workers is as low as two. In longwalls there are 12 miners. In coal faces 9 miners. All persons working "underground" in the mining industry are protected by 2 rescue brigade (2 x 5 rescuers). During each working shift 2 rescue brigade (mines employees) are present underground.
The usual distribution of miners in the mine can vary between 30 and 50 people. There are alarm and evacuation procedures, usually by telephone/tannoy. Otherwise they are alerted by the persons going around contacting them.
Witnesses of the accident should inform the supervisor who is present in the accident area. If there is no supervisor, the witness should inform the mine dispatcher from the nearest phone.
The emergency brigade is a composed by: 2 rescue brigades (2 x 5 rescuers) from the rescue unit the time to reach max 30 minutes
The average time for removing the collapsed material in a gallery is about 2-3 working shifts in the case of miners trapped at a distance of 20-30 m from the rescuers.
The mine control room is normally the point of contact since it operates 24 hour a day.

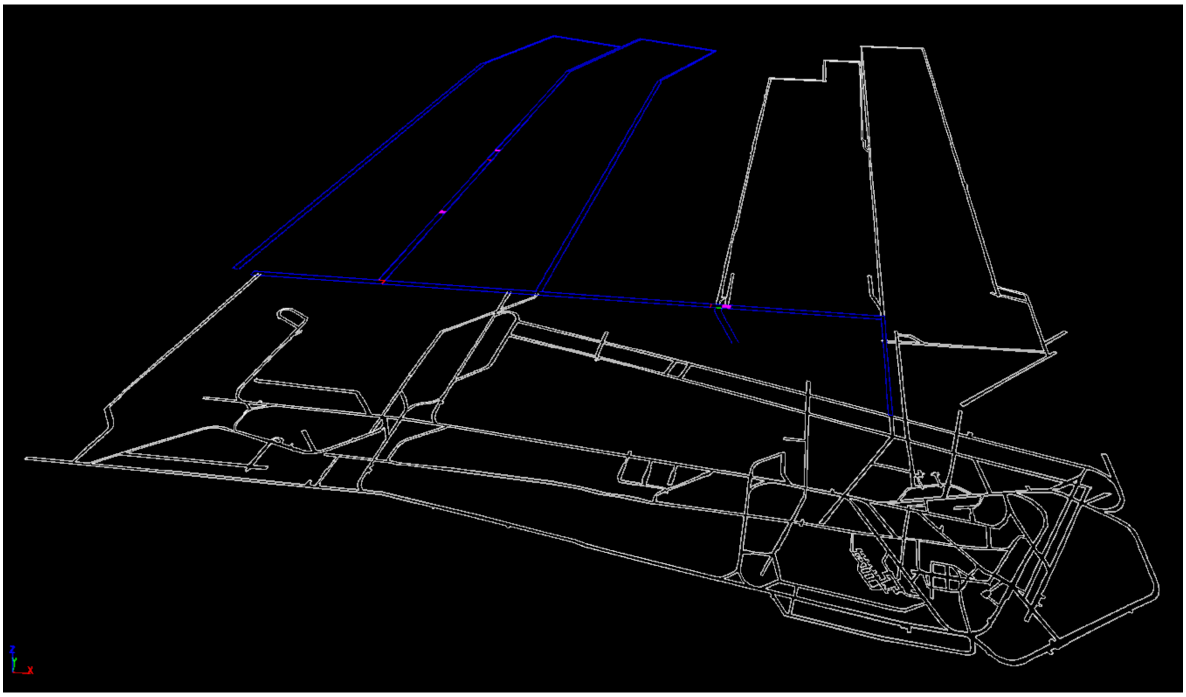


Fig.87: The map of level 850 modeled in STEPs

Simulation Assumptions.

The model represents a part of the mine because there is no need to represent those parts where no miners are affected by the selected scenario.
The times between actions are not to scale. The aim so far is to make clear the steps of emergency procedure and its relationships. The place where the accident takes place is the joint for the longwall and the gallery, a critical place, and walking speed is still not fixed.

Simulation Results
With the precedent assumptions, the following events take part:

- 8 Miners are at the level when accident occurs
- 4 Miners in the collapsed front. 2 get trapped and 2 miners escaped.
- The miners in other places of the level are alerted and go to the collapsed area
- The rescue team, composed of 5 men, enters the level and replaces the miners in the clearing work.
- When the area is cleared, all miners are headed to the mine exit.

The work developed in this task have been materialized in D3.4 as a video of all the simulation process.

KOMAG also realized the computer application which simulates operation of underground tunnels boring machine was developed.. Simulator of boring machine was developed on the basis of Unreal Development Kit environment (UDK), which is now one of the main tools in development of computer games. At the first stage of the project 3D model of boring machine with the original kinematic constraints was developed. The model was placed in an environment recreating the roadway cross-section. Then the model was imported to UDK software environment, where operation of the machine was simulated and relationships between the control system and machine components were defined. In addition, application, which enables testing the communication between the control system and simulator was developed for proper simulation of the machine operation. The application was created in the Visual Basic programme and it enables sending communiqués from the machine control system to the machine simulator. Communication is realized through TCP protocol, which is used for transmission of data between simulated cutting head and control panel. The application module, developed in UDK programme, listens the communiqués generated by the machine controller, using TCP/IP protocol, then after identifying the communiqué, it realizes the functions according to the developed algorithm. In Fig.88 the window of application simulating the operation of boring machine is presented. The application consists of two programme windows: 1 – 3D model of the machine, 2 – control panel of boring machine.

Fig. 88: Window of the application simulating the operation of boring machine

The developed simulator of boring machine enables testing the real control system of the machine as well as presentation of principle of operation of boring machine.

2.3. CONCLUSIONS

Improving the safety of rescue team, its work comfort and effectiveness was the INREQ project objective, realized by the Consortium consisting of KOMAG, CSRG, DMT, GAUK, AITEMIN, GEOCONTROL and ICOP. INREQ Project consolidated all partners on the joint target i.e. development of better rescue equipment as well as devices for communication and monitoring the condition of rescuer body and parameters of the surrounding atmosphere. Two innovative technologies of cutting rock mass were also developed. Majority of the above objectives were completed.
The previously planned water-jet assisted tunnel-boring machine was not realized as the budget appeared to be not sufficient. Instead, the ICOP developed and manufactured the demonstrator device to simulate the machine operation, which positively verified operational parameters and confirmed better effectiveness of rock cutting process with assistance of water-jet stream. Positive results gave a reason for implementation of the technology to TBM machines. KOMAG has developed the control system, which can be adapted for such machine. KOMAG also developed the innovative technology consisting in using the special equipment to break off pieces of rock through drilled boreholes. This technology was verified in tests, but after analysis of the results it has been concluded that this method will not be effective enough.
The aim of the developed rescue devices was to improve the method for tunnel development in the debris area to reach the trapped miners after an underground accident. Lightweight hydraulic legs with internal pump and canopies, lightweight chain conveyor with auxiliary shuttle platform and a lightweight air conditioner supplying cold air to the working area were developed. The prototypes of these devices were manufactured and tested. ATEX certification of the devices was then successfully completed.
The measuring equipment was developed for monitoring the underground climate and rescuers' body parameters. GAUK's existing m-Comm communication system was modified. An additional module for body monitoring and data transfer as well as electronic climate measuring device (CMD) were developed. The CMD can be used separately or in cooperation with m-Comm system via Bluetooth. GAUK and DMT developed very useful devices for monitoring rescuers body condition and parameters of atmosphere. ATEX certification for the CMD was also completed.
The devices developed by GAUK and DMT were left in CSRG to be used. Devices developed by KOMAG are also available to CSRG's rescuers.

2.4. EXPLOITATION AND IMPACT OF THE RESEARCH RESULTS

Actual applications:

The manufactured devices were left for rescuers disposal for further tests and if necessary, they can be used in rescue actions. Final destination of these devices will be decided in future.

Technical and economic potential for the use of the results:
Devices developed by KOMAG have the certificates authorizing to use them in a potentially explosive atmosphere and they can be manufactured by the companies, which made this devices within the project upon the KOMAG's order. Devices developed by GAUK and DMT can also be commercialized. ICOP is going to turn manufacturer of TBM devices to the results obtained on its demonstrator.

Any possible patent filing:

Three patents in relation with the INREQ project was submitted by KOMAG to the Polish Patent Office :
P 411781: Hydraulic leg with internal pump, resistant to dynamic load
P 404 405: Tunnel boring device especially for development of the rescue tunnel in mine underground
P 401488: Tunnel boring method especially for development of the rescue tunnel in mine underground)

Publications / conference presentations resulting from the project:

Kalita K.; Prostański D.: Technologia drążenia tuneli ratowniczych metodą niszczenia spójności skał (Technology of boring the rescue tunnel by the method of destruction of rocks cohesion). Przegląd Górniczy 2012 No.12 p. 86-91.

Cebula D., Kalita M., Prostański D.: Próby dołowe technologii drążenia tuneli ratowniczych metodą niszczenia spójności skał. (Underground tests of boring the rescue tunnel by the method of destruction of rocks cohesion). Maszyny Górnicze 2015 No 1 p. 3-7.

Cebula D.: Wyniki badań dołowych technologii mechanicznego odspajania skał (Results of underground tests on rocks mechanical falling off. Nowoczesne Metody Eksploatacji Węgla i

Skał Zwięzłych. Monografia, Akademia Górniczo-Hutnicza Im. Stanisława Staszica, Kraków 2015 p. 212-222, ISBN 978-83-930353-5-9.

Szyguła M., Mazurek.k., Kozakowski B.: Innowacyjna hydrauliczna obudowa dla ratownictwa górniczego (Innovative rescue suport for mine rescue) Maszyny Górnicze. 2015 No 3 p. 29-35, ISSN 0209-3693.

Drwięga A.: Zespół urządzeń do wykonywania przekopu ratowniczego (The outfit of equipment to perform a rescue tunnel) KOMTECH conference held in Poland (Kliczków) in November 2015

Any other aspects concerning the dissemination of results:

During International Fair of Mining, Power Industry and Metallurgy KATOWICE 2015, in the competition PRODUCT OF THE YEAR - the HOR-01 hydraulic rescue support got 1st degree medal in the category "New machines" (shown below)

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5. LIST OF ACRONIM AND ABBREVIATIONS

ATEX – European approval for safe use of apparatus in explosive atmospheres
CLR – Current Limiting Resistor
CTCSS – Continuous Tone Control Squelch System
CMD – Climate Measuring Device
FEM – finite element method
FSK – Frequency Shift Keying
HEX – Hexadecimal numbering system
HOR- Hydraulic rescue support
ICE – In-Circuit Emulator
IECEx – International Certification System (reg. explosive atmospheres)
IS – Intrinsically Safe (method of making equipment gain ATX approval)
M1 – category identifies equipment that must continue to operate when a potentially explosive atmosphere is present
PCB – Printed Circuit Board
PC – Personnel Computer
PIC – microcontroller chip referred to as PIC, Peripheral Interface Controller
PTT – Push To Talk
SDS – Short data standard
SEM – Product identified by DMT on the project EMTECH
SQL – Structured Query Language
TBM – Tunnel Boring Machine
USB – Universal Serial Bus
UART – universal asynchronous receiver/transmitter
WLAN – Wireless LAN, local Area Network

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